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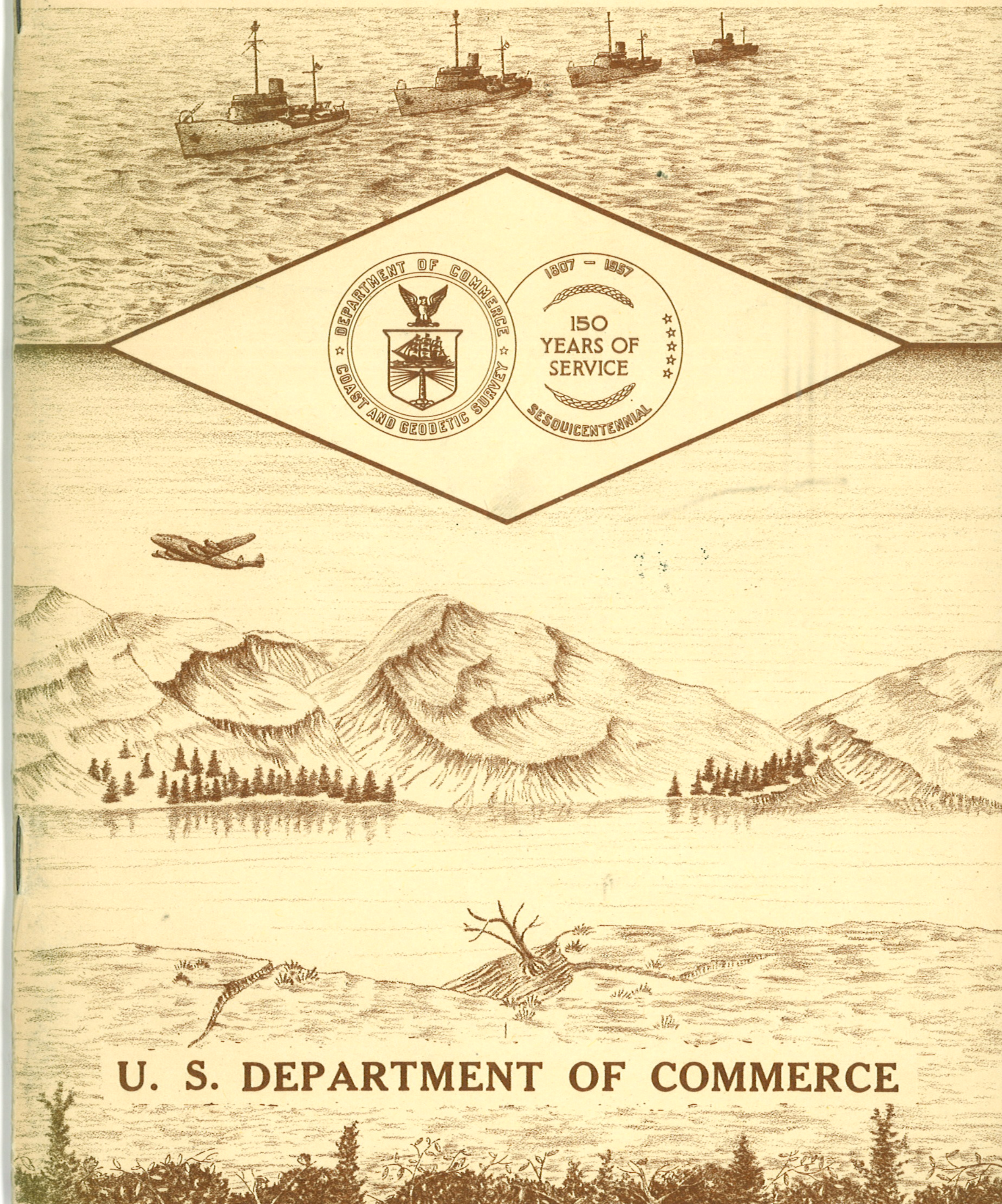
UNITED STATES COAST AND GEODETIC SURVEY PRODUCTS AND FUNCTIONS



U. S. DEPARTMENT OF COMMERCE

The United States Coast and Geodetic Survey Products and Functions

This booklet is a revision of an original article entitled THE UNITED STATES COAST AND GEODETIC SURVEY: ITS WORKS AND PRODUCTS, by Rear Admiral Robert F. A. Studds, former Director of the Coast and Geodetic Survey, which appeared in the July and October 1951 issues of the EMPIRE SURVEY REVIEW. With permission of the Editor of the REVIEW, the two installments comprising the original article were combined and printed in booklet form. A revision of the original text became necessary to up-date and expand the information formerly presented in the superseded reprint. The publication has been of great value in personnel recruiting and orientation, as a briefing handbook on the work and products of the Bureau, and as an effective informational guide in extending the technical services of the Bureau.

U. S. Department of Commerce
Sinclair Weeks, Secretary

Coast and Geodetic Survey
Rear Admiral H. Arnold Karo, Director

General Statement

The Coast and Geodetic Survey is completing in 1957 its 150th year of service to the nation. The activities of the Survey in the fields of engineering, science, and higher mathematics provide facts needed in the planning and execution of many of the activities of the nation; its end-products are indispensable to the day-to-day operations of many lines of business and commerce. Thus this highly technical bureau directly aids the Unites States Department of Commerce in carrying out the mandate of Congress to promote, foster, and develop the industry and commerce of the United States.

Through its field operations the Survey gathers certain raw materials in the form of engineering and scientific data. These data are converted into products essential to water and air navigation, mapping the country and the development of our natural resources. Survey data and publications serve certain strategic purposes vital in national defense. Field surveying parties make observations and measurements, obtain depth soundings and conduct aerial surveys which are forwarded to the Washington office where they are checked, reviewed and compiled into final products suitable for public use.

The production of nautical and aeronautical charts is a major function of the Survey. Sailing directions, tide tables, current tables and tidal current charts are published as supplements to the nautical charts. These and other important products of the Survey have many collateral uses—engineering, industrial and scientific.

One of the basic responsibilities of the Survey is the execution of geodetic control surveys to provide control for maps, charts, intermediate and local surveys and various engineering projects, both public and private. Large-scale topographic and planimetric maps along the coasts of the United States are produced as by-products of the compilation of nautical charts. Aerial photographs are taken to ensure an adequate amount of reliable topographic detail on the nautical charts but other important uses are made of the basic surveys. Tidal surveys are conducted for the purpose of reducing to a common level or datum plane soundings taken at different stages of the tide during hydrographic surveys. Magnetic surveys are conducted as essential operations in the preparation of nautical and aeronautical charts and other purposes. Seismological studies and investigations are carried on for the purpose of mapping earthquake areas and to evaluate earthquake risks through the operation of seismographs and systematic collection of earthquake data.

The demands upon the Survey have grown with the national progress of the United States whose shoreline is now over 80,000 miles in length. Added responsibilities came with the addition of Florida and Texas, the Louisiana Purchase, the discovery of gold in California, the purchase of Alaska, and the addition of Puerto Rico, the Canal Zone, Guam, the Hawaiian and Philippine Islands, and the Virgin Islands of the United States.

Early History

The Coast and Geodetic Survey is one of the oldest scientific and technical bureaus of the United States. During the past century and a half this agency has been a potent factor in developing the commerce of the United States and the world. Operating today as a bureau of the United

He remained in Europe about four years supervising construction and testing and standardizing the instruments built in accordance with his designs. The War of 1812 contributed further to the delay.

At that early date when surveying was incomparably cruder than it is today, the first superintendent realized the magnitude of the job he was undertaking. Basic to his plan was the execution of a system of triangulation along the Atlantic coastline of the new Republic by which all detailed surveying operations thereafter undertaken could be controlled in accuracy with each separate unit fitting exactly into the overall scheme. The control surveys of this country were thus begun and since that time all topographic and hydrographic work undertaken by the Survey has been rigidly controlled by triangulation.

Field work was begun in 1816 with measurements of geodetic base lines at Gravesend Village on Long Island and near English Creek in New Jersey. A small network of triangulation was developed around New York Bay and Harbor. Following this modest beginning all activities of the infant bureau were transferred from the Teasury Department to the Navy between the years 1818 and 1832. Work accomplished during this period was severely limited and in 1832 the Congress enacted new legislation extending the scope of the previous act and reactivating the agency under the Treasury Department with the designation of "Coast Survey."

By this time Florida had been added to the Union and its long coastline was included in the total to be surveyed. Furthermore, the military value of the work in coastal defense was recognized and provision was made therefor. Hassler resumed his task with renewed vigor, aided by officers of the U. S. Topographic Engineers and the Navy. The network of geodetic control so vital to all the work was extended southward along the Atlantic seaboard. When Hassler died in 1843, the triangulation net included the critical areas of Delaware and Chesapeake Bay.

Period of Expansion

In 1833 James Ferguson, who had assisted in the survey of the boundary between the United States and Canada, was appointed first assistant in the Coast Survey. As chief of a survey party he conducted surveys along the north shore of Long Island while Edmund Blunt, the other principal assistant to Hassler, headed a party on Long Island. Four maps were published in 1834 at the scale of 1: 100,000 showing the triangulation scheme in the vicinity of New York, Long Island, and the Connecticut shore but hydrographic details of the off-shore areas were not included.

The first hydrographic survey was conducted in 1835 by the schooner *Experiment* under the command of Lieutenant Gedney in Great South Bay and along the south shore of Long Island. The first Coast Survey vessel to be used extensively in oceanography was the brig *Washington*, which was constructed in 1837 for use as a revenue cutter, but served only during the winters of 1837, 1838 and 1839 in that capacity. During the summers of these years the vessel was loaned for temporary assignment to Coast Survey duty; in April, 1840, she was formally transferred to the Survey.

Topographic surveys based upon the control established in former years were conducted during 1836-38 on Long Island and along the coast of New York, Connecticut and New Jersey. Copperplate engraving was added to the activities of the Coast Survey and in 1842 the first copperplate printing press was obtained. During that year an engraving was completed of the first chart of New York Bay and Harbor.

Professor Alexander D. Bache became the second superintendent of the Coast Survey in 1844. At that time surveys had been extended into nine States with plans for extending the work into four additional States. During the summer of 1846, under the direction of Professor Bache, the first orderly scientific investigation of the Gulf Stream was undertaken. The attention of the scientific world was first directed to the existence of the Gulf Stream by Benjamin Franklin, who was a direct ancestor of Professor Bache.

Reconnaissance preliminary to the survey of the coast of the Gulf of Mexico was started in 1845 and the coast between New Orleans and Mobile was thoroughly examined. Upon acquisition from Mexico in 1846 of political control of the California territory, surveying the Pacific coast of the United States became an added responsibility of the Coast Survey. The first survey of the Pacific Coast was initiated in 1848. Rapid strides were made in copper engraving of charts for various coastal areas and harbors. Many of the copperplate engravings executed one hundred years ago reflect the finest techniques in past methods of chart reproduction.

Anticipating the acquisition of Alaska from Russia, the Coast Survey made extensive plans for surveying the waters and coastal regions of the new territory. When formal transfer of Alaska to the United States was made in October, 1867, George Davidson, an assistant in the Survey, was already in Alaskan waters with the cutter *Lincoln* and a surveying party. During the summer of 1867, the Davidson party made numerous observations and as a result of the season's work charts were published of Sitka and St. Paul Harbors and Kodiak Island. The first Coast Pilot of Alaska was published in 1869 based on the investigations by Davidson. Between 1867 and 1882 the Coast Survey compiled and published numerous charts of Alaskan waters.

Continuous operations were started in 1882 when the ship *Hassler* was sent north and the steamer *Patterson* was assigned to Alaskan waters. During this period triangulation, topographic, and magnetic surveys were conducted, in addition to hydrographic investigations. Upon discovery of gold in Alaska, the rush to the Klondike region in 1897 was served by a survey of the beach at Nome which had been made by Coast Survey ships. The gold rush created new interest in the territory and the Survey was given increased appropriations with which to carry on and expand its Alaskan work.

By Act of Congress in 1871 the Bureau was given the added responsibility of providing geodetic control for the interior of the country, and in 1878 the name was changed from Coast Survey to Coast and Geodetic Survey. At the close of the Spanish American War, the Coast and Geodetic Survey was ready to proceed with the important work of surveying and charting the waters of the Philippine Islands. From 1900 to 1940 much of the original work in surveying the Philippines area was accomplished.

Under normal conditions the work of the Coast and Geodetic Survey is carried on chiefly in the interest of commerce and industry, but with the advent of war it became necessary to rechannel all activities in order to concentrate on projects essential for war purposes. Adjustments were made in the volume of work during war periods to enable the Survey to meet the strategic needs for its products and services. All activities carried on during World War II were planned for maximum contribution to the war effort. Six of the Survey's nine major ships were transferred to the United States Navy. More than half of its commissioned officers were transferred to the Army, Navy, and Marine Corps. A large number of civilian employees joined the military forces.

Many special programs were carried out by the office force as the Survey's contribution to the war effort. Aeronautical charts of various types and at different scales to meet specific requirements were produced for a large part of the world. An extensive war project of major importance was the production of target charts for aerial bombing. Over 1,800 different target charts were prepared including charts covering such important objectives as the Ploesti oilfields in Roumania, and the atom-bombed cities of Hiroshima and Nagasaki.

Organization and Functions

The organization of the Coast and Geodetic Survey is comprised of two forces—office and field. The Director as the administrative head of the Survey is responsible for all phases of the work including standards of performance, efficiency of operations, fidelity of work, and the expenditure of appropriations. The office organization is comprised of the offices of the Director, Assistant Director, Assistant Director for Administration, and twelve divisions. The eight technical divisions are as follows: Coastal Surveys, Tides and Currents, Geophysics, Geodesy, Photogrammetry, Charts, Technical Services, and Instruments. The other four are designated as Administrative Services, Personnel and Safety, Budget and Fiscal, and Organization and Management, and perform administrative and service functions as their names indicate. This organization is shown in Fig. 1.

Coastal Surveys Division.—This Division plans and supervises the execution of hydrographic and associated surveys along the coasts of the United States and its possessions; compiles, edits, and field checks Coast Pilots; directs the construction, operation, and maintainence of the Bureau's vessels and other floating equipment; and conducts research and development in hydrographic survey methods and techniques. Shore parties as well as ships of the survey fleet are utilized in the execution of coastal surveys. The larger ships usually operate as an expedition with combined operations functions. Nine of the 15 field offices operated by the Bureau are largely concerned with work of this Division.

Tides and Currents Division.—This division plans and directs tidal and related oceanographic investigations including the operation of a system of control tide stations, tide and current surveys, and observations of sea water temperatures and densities. Office personnel of the division analyze the resulting data, compute predictions of tides and currents, and publish annual tide and current tables, tidal current charts and other data in the various forms required for use by the Bureau, other governmental agencies and the public. Research is carried out involving studies of tidal and related phenomena and improvements in equipment and methods. The division also collaborates in the operation of the seismic sea wave warning system in the Pacific Ocean.

Geophysics Division.—The magnetic observatories and seismological stations are administered by this Division; also, field parties making magnetic and seismological surveys operate under the Division. Field work pursuant to magnetic operation includes the determination of the value of the earth's magnetic elements, the establishing of magnetic stations, airborne magnetic surveys, the standardization of instruments, and the maintenance of international magnetic standards. Magnetic data of the entire world are collected and compiled into world magnetic charts.

Seismologic work includes the gathering of earthquake information, surveys of important shocks, vibration observations on engineering structures, measurement of ground vibrations, and the operation of a seismic sea wave warning system in the Pacific Ocean. Office activities include the processing and publication of data obtained from field surveys, the location of earthquakes and analysis of destructive earthquake motions, and the development of plans and specifications for instruments and equipment. Basic magnetic and seismic research is carried on in the Division.

Geodesy Division.—This Division is responsible for the operation and administration of geodetic field parties which establish all first- and second-order triangulation, traverse, and leveling in the United States and its Possessions. Other geodetic activities include base line measurement, geodimeter length measurement, astronomic observations of latitude, longitude, and azimuth, and gravity determinations as required for surveying, engineering and research work. Two variation-of-latitude observatories in the United States are operated by this Division.

Office work includes the processing and publication of data resulting from field surveys. Research is carried on involving the mathematical development of map projections, plane coordinate grids, the variation of latitude, figure of the earth, flight of guided missiles, effects of crustal movements, and improvements in instruments and methods.

Photogrammetry Division.—This Division plans and administers the mapping done by the Coast and Geodetic Survey for the production and maintenance of nautical charts, aeronautical charts, and airport obstruction plans. Field work includes aerial photography and photogrammetric field surveys preparatory to map compilation. Large-scale planimetric and topographic maps of coastal areas of the United States and its territories, and large-scale plans of airports are compiled from the aerial photographs, and from the field survey data, by stereo-photogrammetric methods. The Division also conducts research for new and improved photogrammetric methods and instruments, including the design and construction of such equipment.

Chart Division.—This division constructs, publishes, distributes, and keeps up-to-date nautical and aeronautical charts required for sea and air navigation. In fulfilling these responsibilities activities of the Division are divided among four Branches. Aeronautical and Nautical Chart Branches make chart drawings or manuscripts for reproduction. These drawings are processed by the Reproduction Branch and published in final form. The charts are then turned over to the Distribution Branch which issues charts to the user. About 2300 individual charts reproduced in varying quantities to meet demands with new prints and new editions issued regularly to indicate up-to-date changes in navigational data. Subsequent

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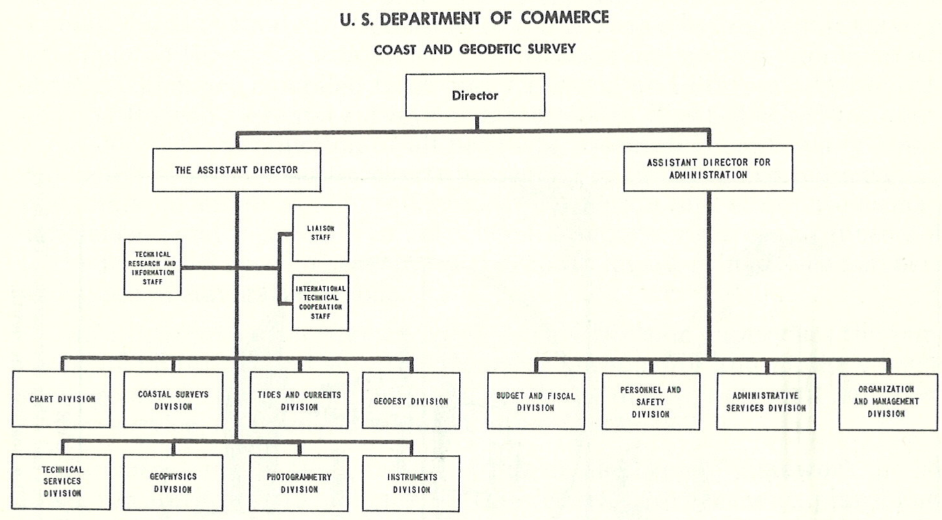

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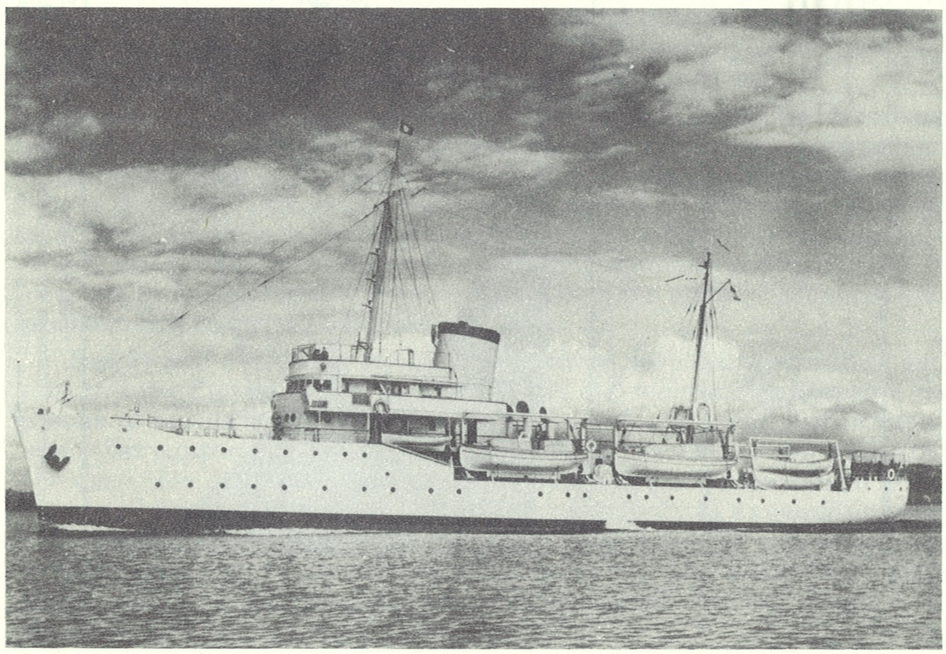

FIG. 2. COAST AND GEODETIC SURVEY SHIP *EXPLORER*.
Equipped with the latest electronic devices, the *Explorer* is one of the main units of the Coast and Geodetic Survey fleet.

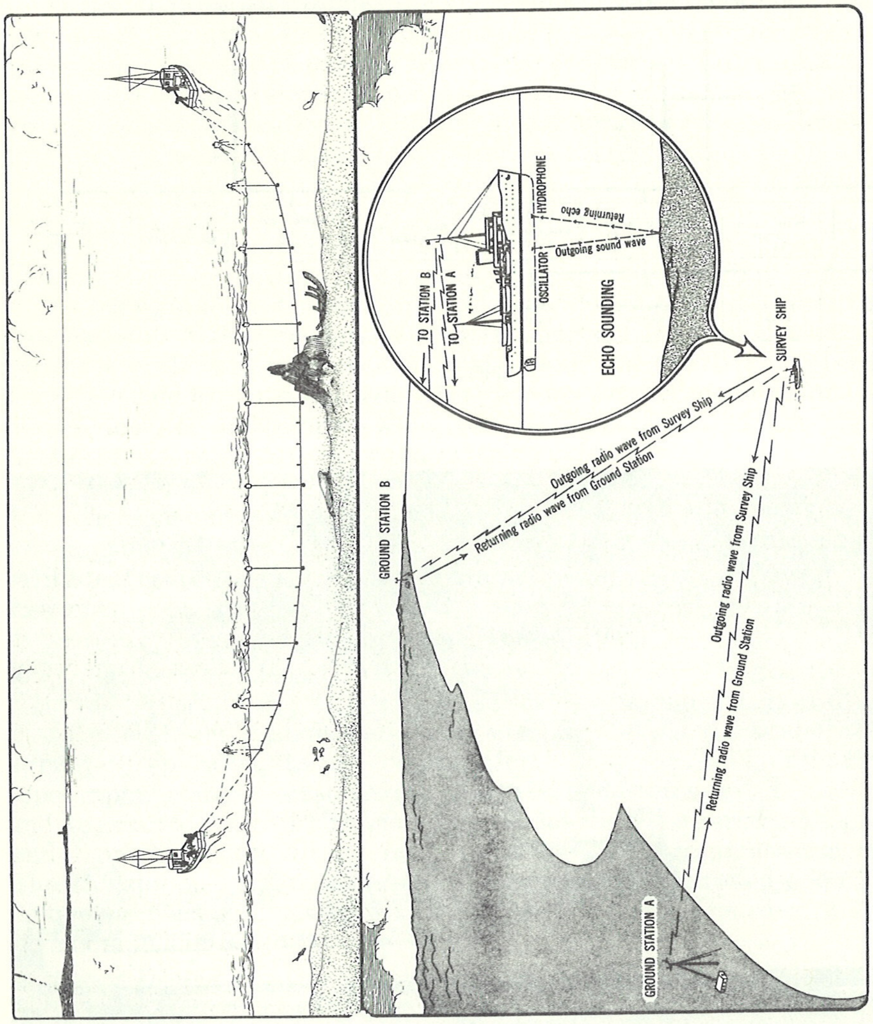

FIG. 3. TWO METHODS OF HYDROGRAPHIC SURVEY.
The top diagram illustrates the use of the wire drag for locating sunken rocks and other obstructions. The lower diagram illustrates the use of electronic devices for determining position and depth.

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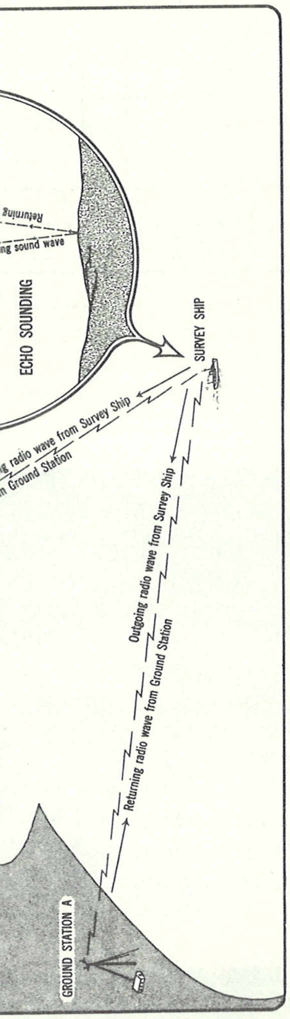

FIG. 3. TWO METHODS OF HYDROGRAPHIC SURVEY.
The top diagram illustrates the use of the wire drag for locating sunken rocks and other obstructions. The lower diagram illustrates the use of electronic devices for determining position and depth.

critical changes are made by hand before distribution of nautical charts, and many items of the published notices of dangers and aids to sea and air navigation are regularly prepared by this Division. Source material is processed and evaluated. Processing of the Bureau's hydrographic surveys is completed through a procedure of verification and review. Aeronautical charts, which are compiled from many Federal and State maps, reports, and the Bureau's ground surveys at airports, are flight-checked for accuracy. As in the production of all products, research is continually being conducted to provide better charts by using new drafting and reproduction materials, mechanical aids to increase production and eliminate human deficiencies, and to simplify complex symbolizations which are so important to the increased speed of modern navigation in an era of increased numbers and types of navigational aids.

Administrative Services Division.—This Division supervises the purchase of materials and services, property accounting and motor vehicle management, storage, shipping and receiving of supplies, mail and messenger service, and general administrative functions.

Personnel and Safety Division.—Within the broad framework of the laws, regulations and policies of the federal government, plans and procedures are developed by this Division to provide uniform administration of the Bureau's personnel and safety programs. It is the objective of Bureau management to construct and maintain a workforce of maximum effectiveness through pursuing policies (1) for equitable pay and recognition for services rendered; (2) for objective selection, training and provision of opportunities for advancement; (3) for realistic employee services; and (4) for aggressive safety and accident prevention measures.

Organization and Management Division.—This Division provides advice and assistance and conducts surveys and studies relating to organization, staffing, methods and systems, work flow, and other management activities to promote efficiency and economy throughout the Bureau. It develops and coordinates special programs such as forms control, records management, motor vehicle management, and management improvement. It reviews and implements Department and other agency issuances and prepares and coordinates Bureau issuances.

Budget and Fiscal Division.—This Division develops, formulates, and executes the Bureau budget and establishes and maintains a Bureau-wide system of accounting. It prepares the Bureau estimates and justifications and other supporting data; assists in the Budget presentation; evaluates the execution of the budget and recommends apportionments and allotments of funds by program. The Division maintains expenditure and obligation controls and accounts; maintains a Bureau-wide cost accounting system; administers payroll and leave functions; and performs related fiscal activities including the examination, audit, and certification of vouchers.

Technical Services Division.—This Division provides central service to the Bureau and the public in the furnishing of cartographic source data and related information. It collects, evaluates, catalogs, and stores source material from other Government agencies, maintains the Bureau cartographic archives, and provides geographic names research for map and chart compilation. It maintains the Bureau Library and furnishes materials for technical papers and publication articles, prepares exhibits, and provides special cartographic and art services. It maintains the Bureau essential records program and acts as the publications review and control office for the Bureau.

Instrument Division.—This Division is responsible for the invention, design, development, maintenance, construction, storage, and issue of instruments used in hydrographic, topographic and geodetic surveying, earthquake recording, study of terrestrial magnetism, and tides and currents surveys. Special instruments and machines are developed for chart reproduction. The Division is also responsible for development of electronic equipment for determination of ocean depths, and for measurement of distances, particularly at sea.

Field Offices.—These offices supervise and direct all fixed Bureau functions located in the respective districts except Latitude and Magnetic Observatories. Field data, including those resulting from hydrographic surveys, are processed in these offices; other activities include the computation and adjustment of geodetic data and the compilation of topographic and planimetric maps. Studies and recommendations are made for surveys for the construction and maintenance of nautical and aeronautical charts; for obtaining geodetic control data for private and public engineering use; for obtaining magnetic and seismological data; and for obtaining airport obstruction plan data. Close liaison is maintained by the field offices with Federal, State, and local government agencies, and private organizations and individuals for the purpose of gathering and disseminating data relative to nautical and aeronautical charts and geodetic control. A library of charts and other Bureau publications is maintained in each office for reference purposes. Another important function is the supervision of the establishment and inspection of agents selling Bureau charts and publications.

The field offices are located in principal coastal cities and several interior points. They are under the direct supervision of the Assistant Director. The offices concerned largely with coastal surveys and nautical charts are: Boston, New York, Norfolk, New Orleans, Los Angeles, San Francisco, Seattle, Portland, Oregon, and Honolulu. Photogrammetric operations are carried on at offices located in Baltimore, Tampa and Portland, Oregon. Aeronautical charting liaison is the principal function of the offices located in Kansas City and Fort Worth.

Personnel

Personnel of the Coast and Geodetic Survey consist of two major groups—commissioned officers and civilian personnel. Employment is in the Washington office and in the field service throughout the forty-eight States of the United States, its Territories and Possessions.

Commissioned personnel include the Director of the Bureau, who is a Rear Admiral (upper half) and the Assistant Director, who is a Rear Admiral (lower half); other officers range in rank from Captain down through Ensign. These officers, who are all engineers with additional technical training in the specialized work of the Bureau, hold administrative and key positions both in the Washington office and in the field service.

Civilian personnel are comprised of four types: (1) professional employees including mathematicians, geophysicists, and technical experts highly trained in various fields of engineering such as cartography, photogrammetry, geodesy, hydrography, and electronics; (2) semi-professional personnel comprised of cartographic aids, survey aids, draftsmen, scientific aids, instrument makers, cabinet makers, lithographic artists, and other employees specially trained in reproduction methods; (3) administrative, clerical, and custodial employees including personnel officer, budget officer, placement officer, administrative officers, accountants, secretaries, stenographers, clerks and messengers; and (4) crew members attached to the vessels of the Survey now in active service.

On January 1st, 1956, there were more than 150 commissioned officers and nearly 2000 civilian employees in the Coast and Geodetic Survey. Of these, about 900 were on duty in the Washington office, more than 250 were assigned to permanent field installations, 900 were engaged on field work attached to vessels and mobile field parties and about 40 were employed on a part-time basis as tide observers and seismograph tenders.

Recruitment of Officer Personnel.—Initial appointment in the Bureau of officer personnel is to the position of deck officer. Candidates must be citizens of the United States, between the ages of 20 and 26 years. A prerequisite for consideration for eligibility is that applicants must be graduates, preferably in civil engineering, from a college or university of recognized standing. Deck officers are assigned to ship or shore parties engaged in any of the numerous surveying operations of the Survey. Deck officers serve for six months before being eligible for commission as Ensign—the lowest rank in the commissioned corps.

The mental and physical examinations for appointment and promotion of commissioned officers are conducted by a board appointed by the Secretary of Commerce, consisting of not less than five senior commissioned officers of the Survey.

Selection of Civilian Personnel.—The majority of the civilian employees of the Survey are selected through examinations given by the United States Civil Service Commission. This group includes the top-level employees who serve as administrative heads of technical and administrative branches and sections of the Survey; world-renowned experts in the fields of oceanography, hydrography, geodesy, geophysics, and seismology; professional employees in the Washington office; and a great majority of the semi-professional field employees.

Those semi-professional field employees who are not recruited through the Civil Service system are employed for short periods of time by chiefs of mobile field parties who recruit locally in the area in which the field party is in operation. Recruitment of crew members is conducted by the commanding officers of the various vessels at their home ports without recourse to civil service registers.

Personnel Training.—In selecting personnel for employment in the Survey, great care is exercised to obtain the candidate with the best possible qualifications for each position. But due to the specialized nature of the work, it is not always possible to obtain personnel who can, without additional training, assume the full responsibilities of many of the positions.

Therefore, on-the-job training is an important aspect of every employee's duties. In the commissioned corps this on-the-job training begins upon initial appointment, and is supplemented by specialized training programs conducted by experienced officers in specific fields. Also, rotation of field assignments gives both commissioned and civilian personnel an opportunity to obtain experience and training and for wider application of their engineering background.

Safety.—Because of the unusually hazardous nature of much of the work of the Bureau, the aggressive pursuit of a positive safety program is considered a major responsibility of the management of the Bureau. It has been determined that the alignment of this function with the personnel program is a logical and effective organizational plan. In his work as safety officer, the Chief, Personnel and Safety Division, is assisted by a Safety Committe comprised of representatives of all operating divisions and by deputy safety officers throughout all activities including field parties and vessels. It is the policy of our Bureau to look to all supervisory personnel to provide the real safety leadership in daily operations with the safety officer, his deputies and committee serving as advisors and offering assistance in the implementation of the program.

Surveying Vessels and Equipment

For well over a century, vessels of the Coast and Geodetic Survey have carried on extensive surveying operations in the coastal waters of the United States, Alaska, Puerto Rico, the Virgin Islands, Panama, the Hawaiian and Philippine Islands, Midway and other islands of the Pacific.

Before the turn of the century sailing vessels were used extensively in conducting hydrographic surveys. The change from sail to steam and from wood to iron resulted in an immense difference in the efficiency and capabilities of the surveying ship. Gradually steam-driven vessels came into general use until sail completely disappeared during the early part of this century. For the past fifty years the surveying fleet has been almost entirely dependent on steam. Great were the handicaps under which the early surveys were executed and it is astonishing that so much accurate and detailed information was obtained and charted.

The historical record of the Survey notes many instances of great hardship encountered in surveying our coastal waters. An outstanding experience when great courage and endurance were displayed under extremely hazardous conditions was during the near-loss of the brig *Washington* in 1846. The *Washington,* after her successful cruise in the Gulf Stream during the summer of 1846, was caught in a hurricane during her return to port. The brig was severely damaged and would have been lost except for the superb seamanship of both officers and crew. After floundering for more than a week, the vessel reached port but not before the commanding officer and ten members of her crew were lost.

Among the last of the sailing vessels used in Coast Survey work was the schooner *Matchless,* which was regarded as the most handsome of the sailing fleet. She was a two-masted center-board vessel, measuring 97½ feet in length with 24¼-foot beam and 8-foot depth of hold. The vessel was elaborately furnished throughout with roomy quarters for officers and crew. The chart-room was large and bright. For many years this vessel was used as a training ship.

As early as 1847 the Coast Survey used the first steam-driven vessel in hydrographic surveying. The first vessel of this type was the *Bibb*, of wood construction, which was used along the east coast of the United States. The *Jefferson*, the first steam vessel of iron construction, was obtained by the Coast Survey in about 1849.

At the beginning of the present century the Coast and Geodetic Survey had in service a number of specially-built steam-driven surveying vessels. In addition to the coastal waters of the United States these vessels were used extensively in Alaska and the Philippine Islands. Much of the original work in surveying the coasts and adjacent waters of the Philippines was accomplished by our fleet of surveying vessels.

At the outbreak of World War I selected vessels of the Coast and Geodetic Survey were transferred to naval duty. The *Surveyor* was one of the vessels taken over by the Navy and was especially active on extensive escort and convoy duty in the Atlantic Ocean and Mediterranean Sea. Manned by officers of the Survey, the ship participated in several submarine engagements, including an attack in May, 1918, by two German submarines on a convoy to which she was attached as an escort. One of the submarines, the U-39, which had previously sunk the *Lusitania*, fired a torpedo at the convoy which grazed the bow of the *Surveyor*. The wake of the submarine was picked up by the *Surveyor* and she was able to deliver an effective depth-charge. The vessel could not leave the convoy to finish off the submarine but the U-boat was disabled to the extent that it was compelled to enter the port of Cartagena, Spain, there to be interned.

Our surveying fleet is comprised of about 17 ships; four of which are major sea-going vessels and the remainder are smaller types, 136 feet or less in length. The minor vessels are used for surveying in bays or inshore areas. The sister ships, the *Pathfinder* and *Explorer*, are outstanding examples of our modern specially-built surveying vessels which are among the major units of the fleet. These ships were designed and constructed for the Survey. The *Pathfinder* is 229 feet in length, draft 15½ feet and has a displacement of 2,000 tons. The *Explorer* is essentially the same in design, except that the *Pathfinder* is about 10 feet longer. Launch and small-boat equipment normally carried by these ships includes four diesel-powered launches, four whaleboats, two dinghies, six skiffs and dories, and two rafts.

Both vessels carry the latest types of instruments and equipment developed for use in hydrographic surveying. Echo-sounding equipment includes both the NMC-2 and EDO instruments having maximum range of 6,000 fathoms; and six portable recording echo-sounding instruments for use in the survey launches. One low-frequency and two intermediate-frequency transmitters and a number of portable units for ship-launch and ship-shore voice communication are included in the radio equipment of the vessels.

The modern surveying vessels now in use, fully equipped with the latest types of surveying instruments, make possible the more critical surveys necessary to produce adequate nautical charts to meet present-day maritime demands. Progressive developments through pioneer work in improving the means and methods of conducting surveys together with improved charting techniques, have given the nautical chart its present high standard in precision and scientific status.

To facilitate off-shore surveys along bold and rugged coasts, with large and abrupt irregularities in depth, and many pinnacle-like rock masses, the Survey has developed the equipment known as the Wire Drag. This method of determining depth has been of inestimable value in surveying in the Long Island Sound region, where huge boulders were deposited by the ice of the glacial period. In the Florida Keys large coral heads rise well above the surrounding bottom. Parts of Alaska and the northern half of our New England coast are even more rugged with great seamounts rising to within a few feet of the surface.

The wire drag consists of a horizontal wire maintained at any desired depth below the surface by an arrangement of weights and adjustable upright cables which extend up to small buoys on the surface. The apparatus is towed by two vessels, one at each end. The horizontal wire will catch as the drag passes through the water and thus will indicate the location of any obstruction which extends above a plane at the depth determined by the setting of the horizontal wire. The exact location of the obstruction having been thus found, the least depth on it can then be determined by fathometer or by leadline.

Many improvements have been made in the wire drag since it was first introduced in 1904. The length of the wire drag in use today can be adjusted as necessary to cover a sweep up to twelve to fifteen thousand feet. As a result of successive improvements, the drag is now used to determine whether or not apparently clear water areas are free from obstructions; to discover and locate all obstructions in a shoal area; and to determine the maximum safe depth of a channel. The effectiveness of the improved wire drag is indicated by the fact that in the tens of thousands of square miles of water area dragged by the Survey more than 5,000 uncharted obstructions have been discovered.

Hydrographic Surveying

Hydrographic surveys which determine the depths of water and the character of the sea bottom were formerly obtained with the handlead, deep-sea lead, or the pressure tube, and dangers were searched for with wire drag. During the past two or three decades considerable improvements have been made in hydrographic surveying methods with the development of echo-sounding equipment and improved methods of control. Accurate profiles are now obtained of the ocean floor which provide the cartographer with a wealth of information for detailed charting of submarine relief often characterized by intricate and distinctive patterns.

The hydrographic survey starts with the high-water line and control points as they appear on the topographic survey. In general, hydrographic surveys are extended inshore across the low-water line in areas where this is practicable and can be done without danger to personnel or equipment. The low-water line, one of the most important depth curves in a survey, is fully developed in our hydrographic surveys wherever tidal conditions permit.

Experience has shown that the most effective method of surveying an inshore area where the bottom slopes gradually is by means of a system of sounding lines parallel to the beach. Such lines can be run close to shore since the surveying launch is traversing a course parallel to the danger line rather than toward or away from it. Periods of high tide and d and rugged coasts, with d many pinnacle-like rock nt known as the Wire Drag. of inestimable value in sur- where huge boulders were the Florida Keys large coral m. Parts of Alaska and the ven more rugged with great urface.

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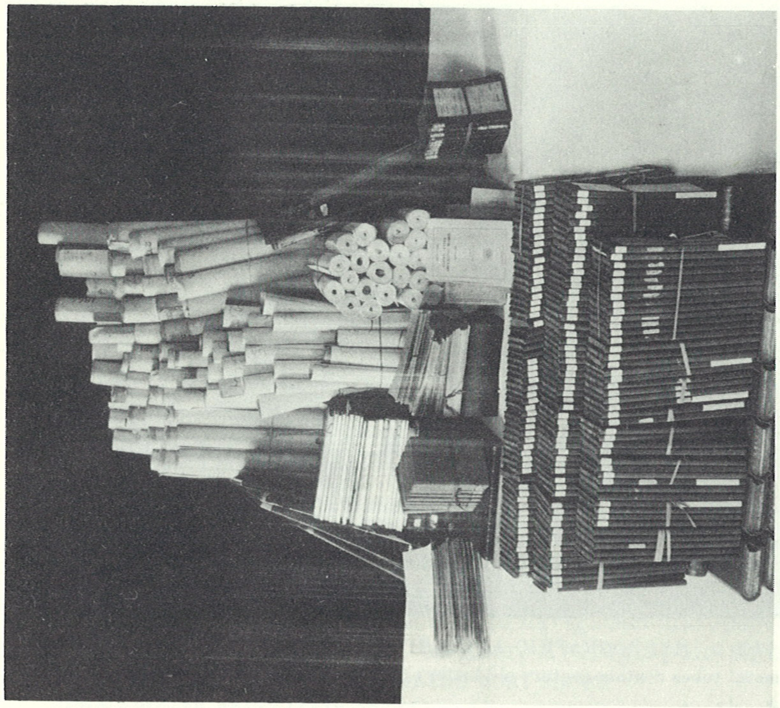


FIG. 5. MATERIAL REQUIRED IN THE MAKING OF ONE NAUTICAL CHART.

To show all available information necessary for safe marine navigation, charts prepared by the Coast and Geodetic Survey are published in relatively small editions based on extremely detailed data, and must be constantly revised to keep up with the man-made and natural changes in coastal waters.

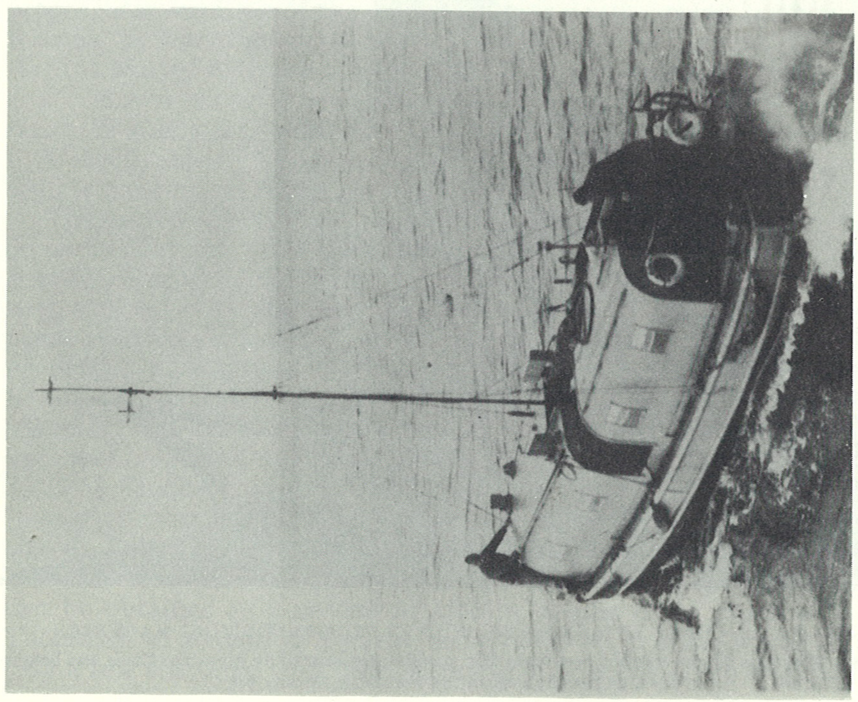


FIG. 4. 36-ft. LAUNCH WITH SPECIAL SHORAN MAST.

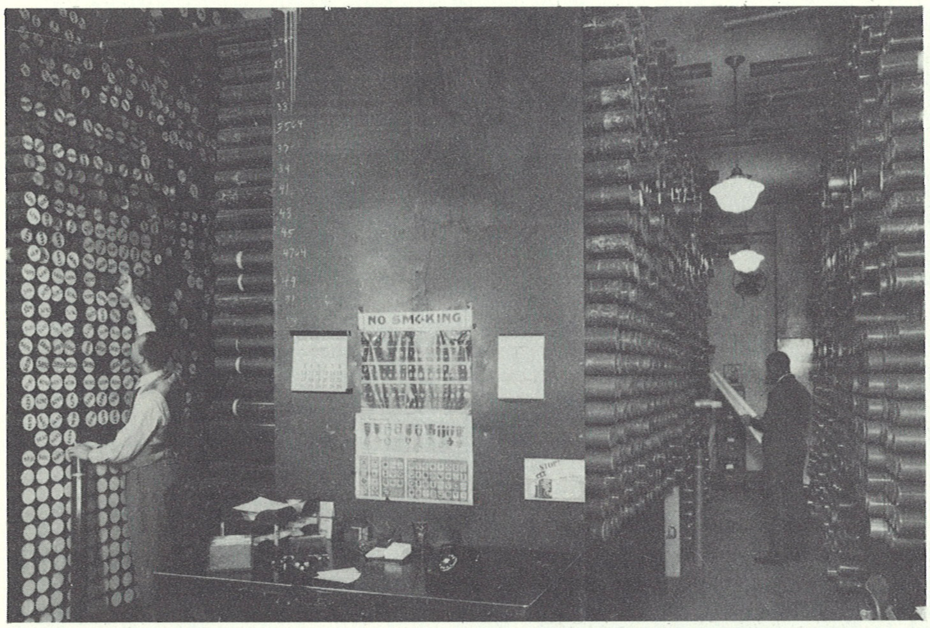


FIG. 6. HYDROGRAPHIC AND TOPOGRAPHIC SURVEYS.
These metal tubes contain century-old history of American coastline evolution.

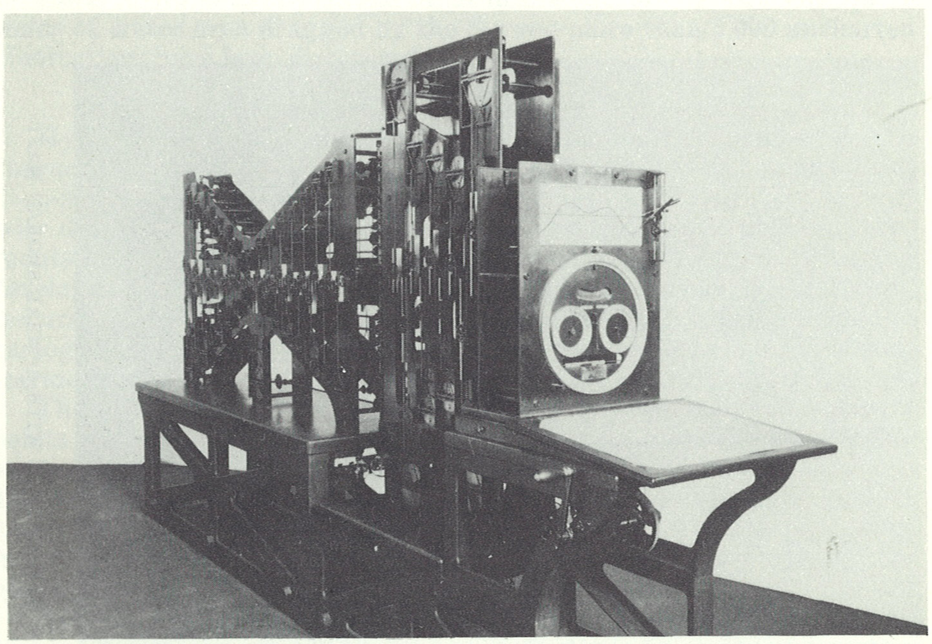
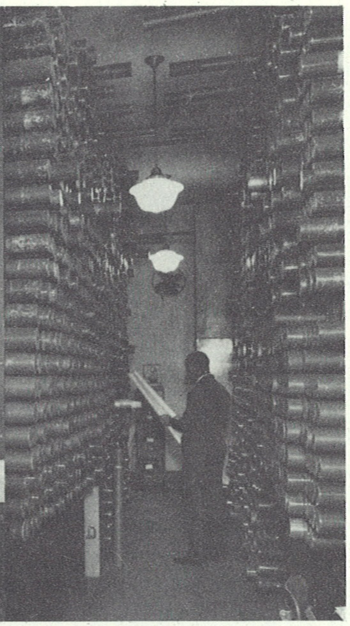


FIG. 7. U.S. COAST AND GEODETIC SURVEY TIDE-PREDICTING MACHINE.
When set to certain predetermined constants this machine automatically gives the times and heights of the tide for any port in the world and for any year.



.APHIC SURVEYS.
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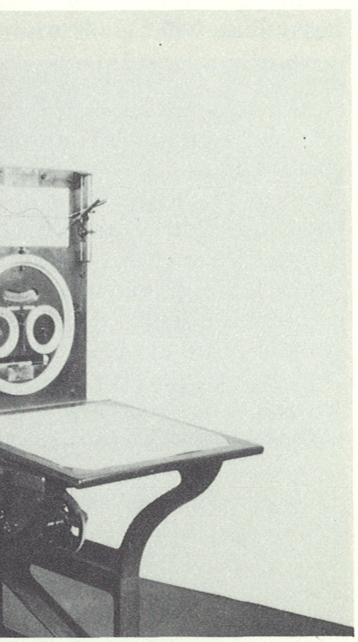

IDE-PREDICTING MACHINE.
tomatically gives the times and heights
nd for any year.

calm weather afford the best conditions for inshore sounding and our operations are planned to take advantage of these.

The hydrographer endeavors to obtain depths which will develop the area and delineate submarine relief in a thorough and economic manner by the methodical system of evenly-spaced sounding lines. The first line of soundings is run as close to the high-water line as practicable. The lines of soundings nearest to shore are closely spaced with the two inshore lines spaced not more than 50 meters apart. The spacing of the system of lines is increased gradually until a maximum is reached between the two outermost lines. Under many conditions a system of sounding lines parallel to the beach is impracticable. It is then necessary to use a system of evenly-spaced sounding lines approximately normal or at an angle of 45 degrees to the depth curves.

Soundings, the basic element of the hydrographic survey, are recorded on a work sheet by the hydrographer as the work progresses. The *boat sheet,* the designation given the work sheet, is used principally for plotting each position of the sounding vessel as the observations are made. In addition to the soundings, the boat sheet includes the locations and names of all control stations with descriptive notes added where necessary to identify a specific station. The boat sheet for an inshore hydrographic survey also contains the high-water line, the low-water line, the approximate limits of shoal areas, rocks, aids to navigation and suspected dangers. Sextant cuts to locate a rock, breaker, hydrographic signal, or other features are carefully plotted on the boat sheet.

The *smooth sheet* (fair sheet) is the name given to the hydrographic survey when reduced to plot form. It is essentially a record of the soundings taken during the field survey but contains other data necessary for a proper interpretation of the survey, such as depth curves, bottom characteristics, names of geographic features, and control stations. The smooth sheet is plotted with the utmost care and after being registered, verified, and reviewed in our Washington office it becomes the official permanent record of that particular survey. It is as complete for the water area as it is practicable to make it, and subsequent reference to the original sounding records is rarely necessary.

The polyconic projection is used to plot the result of our surveys. This projection devised by Ferdinand Hassler (first Superintendent of the Coast Survey), is especially adaptable for surveys of comparatively small areas such as those covered by our hydrographic and topographic surveys, because it effects a satisfactory compromise with all the most desirable properties of map projections, because of its ease of construction, and because a general table for its use has been calculated for the entire spheroid (C. & G.S. Special Publication No. 5, *Tables for a Polyconic Projection of Maps and Lengths of Terrestrial Arcs of Meridian and Parallels).*

Echo Sounding.—One of the oldest electronic surveying equipments is that employing echo sounding to determine the depth of water under the vessel. This method is now used almost exculsively in the hydrographic work of the Coast and Geodetic Survey. With this equipment, soundings can be obtained in a second or two in depths of as much as a mile. Thousands of soundings are now being obtained in areas where formerly only a few scattered ones were economically feasible. The original equipment depended upon audio and visual methods, whereas, practically all equipments now in use are of the recording type. The recorders connected with the sonic sounding devices provide a continuous profile of the ocean floor showing the ridges, and depressions on a permanent visual graph. The dial-type echo-sounder, known as the *Dorsey* Fathometer, is a precision instrument designed by the Coast and Geodetic Survey.

The principle of echo sounding is the sending out of a sound impulse from the transceiver in the hull of the ship which on reflection from the ocean floor is picked up by this same unit and amplified so that it will make a permanent mark on a graphic record. The effect of many consecutive soundings is to produce a profile of the ocean floor on the graph. Depths of water are measured accurately by measuring the small intervals of time required for the sound to make the round trip to ocean bottom. Although round trip times are measured, only half of the measured values are recorded.

Echo-sounding equipments may be divided into two classes, those for relatively shallow water, such as obtained within a few miles of the shore, and those which will record depths in very deep water. Most of the smaller or shoal-water equipments are portable and may be used in launches as small as 25 feet in length. Portable echo-sounders are used in the surveying of harbors, bays, rivers and inshore areas along our coasts. This type of equipment is also installed in larger survey vessels for work in waters which are relatively shoal yet extending many miles offshore, as in the case of the Gulf of Mexico where depths of only 100 fathoms exist 100 miles offshore. Fathograms recorded by these equipments can be read to 0.1 foot if desired.

Deep water echo-sounders are, of course, used only in the larger ships and many are equipped with them for navigational uses. Most types of these equipments will record the profile of the bottom in depths ranging from a few fathoms to those exceeding 4,000 fathoms (or 4½ miles). These recordings are made with a reading error of less than 10 fathoms in maximum depths and ranging to about 2 feet in the shoal areas. The larger ships are equipped with both a shoal and a deep-water echo-sounder so that all conditions of depth may be examined.

Many submerged features of interest have been found by using echo sounding methods. Mountain peaks rising to heights of 10,000 feet or more have been found in ocean depths of 2,000 or 3,000 fathoms. Great trenches have been found along the continental shelf which drop to depths of more than 4,000 fathoms from a surrounding general level bottom not much deeper than 2,000 fathoms. By means of echo-sounding equipments intensive surveys have been made of vast areas along the coasts of the United States and Alaska.

Hydrography accomplished annually averages more than 75,000 miles of sounding lines over areas totalling 25,000 to 30,000 square miles. In addition, about 200 square miles of water areas are wire dragged each year.

Control of Hydrographic Surveys.—The methods usually used to control hydrographic surveys depend on the distance from land and the depth of water. Where the survey vessel is close to shore its position or the position of the soundings is obtained from control stations on shore. The usual method of fixing hydrographic surveys within sight of land is by sextant three-point fix which is almost universally followed for position-fixing.

Beyond the limits of shore objects and where the use of buoys or three-point fix control is impracticable or unwarranted, a number of methods of control have been used in the past. Radio Acoustic Ranging, or RAR, including the radio-sono buoy, was a method developed by the Survey after World War I for offshore hydrographic surveying. By this method the position of the survey ship was determined from two or more previously located control stations by exploding a small bomb in the water near the ship and measuring the interval of time required for the sound to travel to each station. The explosion of the bomb and the radio signals that were transmitted automatically from the control stations were recorded on a chronograph carried aboard ship. The distances from the survey ship to the control stations were determined by measuring the time for the transmission of the underwater sound impulse and the ship's position was thus determined.

The application of these scientific principles resulted in the extension of hydrographic surveying to considerable distances offshore with increased accuracy. This method was hailed as a great achievement and an enormous area was surveyed using the system. There were, however, several disadvantages inherent in RAR, none of which was completely overcome. World War II brought forth several new navigational methods which have made possible great improvements in our system of controlling surveys. As a result of these developments Radio Acoustic Ranging has been replaced in the hydrographic operations of the Survey.

The Coast and Geodetic Survey was the first agency in the United States to use Shoran for control of hydrographic surveys. The very great accuracy of the Shoran fix has made it an essential control method for hydrographic surveys. The system was first tested in 1945 aboard the Coast and Geodetic Survey Ship *Explorer* in the Aleutian Islands, Alaska, to determine its application in precisely locating a survey ship while traversing back and forth on depth-finding operations. The tests proved successful and Shoran is now used on all the Alaskan survey vessels as the standard method for ship control. Vessels controlled by Shoran are able to take soundings day and night, in fog and clear weather, continuously knowing the location of the vessel within an area of uncertainty of about 20 feet.

Shoran equipment is a special type of Radar system designed and built by the Radio Corporation of America for the particular purpose of controlling the position of an aircraft during a bombing mission. The fact that the equipment was designed to be used in and transported by aircraft is reflected in the general design of all components, including the power sources. The variation of our equipment from the original design is in the modification of the standard airborne equipment to serve as the beacon at the fixed control stations ashore.

Shoran being a line-of-sight method is limited to distances of 50 to 70 miles. While very accurate in its determination of a position, the system provides a relative small service area, especially when equipments are installed at low elevations. An improved method of control was offered by the Loran system which utilizes low frequency radio impulses for transmission. Therefore an adaptation of Loran is not limited by the line-of-sight range, as is the case with the high frequency pulses of Shoran. By combining the frequency and modulation of Loran with the distance measuring features of Shoran, the Survey built the *Electronic Position Indicator*. The principle of position fixing with the E.P.I. is essentially the same as Shoran with a greatly increased service area.

Field tests made during the summer of 1945 were sufficiently gratifying to warrant further research and development in the system. The following months were spent in further design and engineering and the equipment now known as the Mark III, Model 2, has been developed. Field tests on this equipment have produced results fulfilling all expectations. Accurate control is now being obtained at distances ranging up to 400 miles. Recent tests have indicated a maximum usable range of about 540 statute miles without appreciable reduction in signal strength. Three of the major ships operating in Alaskan waters were equipped with this system of control for use during recent seasons.

Tide and Current Surveys

Observations and investigations of tides and currents are carried on by the Coast and Geodetic Survey to provide basic data for the surveying activities of the Bureau as well as to supply essential information for safeguarding maritime commerce, for aiding engineering projects associated with the commercial and industrial development and protection of coastal property, as well as for various scientific, legal, recreational and defense purposes.

In nautical chart production soundings taken during hydrographic surveys must be adjusted for the height of the tide so that the chart will show all depths referred to the same low-water datum. In photogrammetric surveys of our coast line, the aerial photographs must be correlated with the stage of the tide at the time of photography so that the high water line and the low water line can be accurately delineated from the photographs. In geodetic control surveys the sea level datum used in the network of leveling is determined from observations at selected control tide stations distributed along our coasts.

Advance data relative to the rise and fall of the tide and the accompanying ebb and flow of the current are important aids to marine navigation. Such information is made available through the publication of annual tide and current tables, and tidal current charts. Further dissemination of the information is obtained through the tidal predictions supplied by the Bureau to newspapers, radio stations, and private publishers of almanacs and calendars.

The daily predictions published in the tide and current tables are calculated by a tide-predicting machine which was designed and constructed by the Coast and Geodetic Survey. It is about 11 feet long, 2 feet wide, and 6 feet high, and weighs a little over a ton. This machine not only traces a continuous curve showing the variation of the tide or current hour by hour throughout the year but also indicates by dials the time and height of each high and low water, or the time of each slack water and the time and velocity of each strength of current that will occur every day of the year. To increase the production and usefulness of the machine, equipment recently has been attached which automatically types the

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In the commercial and industrial development of coastal property, information on tides and currents is needed for the location or design of piers, bridges and plant installation; for the determination of boundaries of water-front property; for offshore oil production projects; and for the solution of problems of sewage disposal and water pollution. Authentic tide gage records obtained by the Bureau also are required for investigations and actions associated with litigations, insurance, warnings and protective measures related to extreme water levels caused by hurricanes.

Supplementing these principal uses, there is an increasing demand for tide and current data for collateral uses, such as fisheries, sports and recreational activities, and for investigations of slow changes taking place in the relation of land to sea.

The tidal program of the Bureau includes the operation of a system of control tide stations distributed along our coasts and on certain islands. The basic data from these tide stations are supplemented by short period observations from stations occupied during hydrographic surveys. A system of tidal bench marks is established by the Survey at each tide station to provide permanent reference points for the observed heights of the tide and the tidal datum planes determined therefrom.

Observations of the temperature and density of sea water are taken at most of the tide stations maintained by the Bureau as well as at a number of other locations. The data derived from these observations supply useful information to the shipping and fishing industries, to industrial plants using salt water, and to various scientific organizations.

Comprehensive current surveys are carried out by the Bureau to provide detailed information on the circulation of the tidal waters in our important harbors and waterways. The prosecution of these surveys, particularly those covering large areas, has been greatly facilitated by the use of radio current meters and recorders designed by members of the Survey.

Geodetic Surveying

As the name of the Coast and Geodetic Survey indicates, it is the agency of the United States Government which is responsible for geodetic control surveys. Originally our geodetic surveys were made for control of surveys of the coast and to provide a proper base for the nautical charts of the coastal waters. By Congressional action in 1871 these activities were expanded to furnish basic control for the interior of the country, including geodetic connections between the Atlantic, Gulf, and Pacific coasts of the United States.

The geodetic work of the Coast and Geodetic Survey consists of the field surveys and office processing necessary for the determination of points in the basic national networks of horizontal control and vertical control, and also includes gravity and geodetic-astronomic determinations. These geodetic surveys take into account the ellipsoidal figure of the earth, and are of the highest type of surveying. Precise geodetic control is in demand by all topographic mapping interests public and private. Geodetic control is used in water resources planning involving geologic and hydrographic surveys, in soil and cadastral surveys, in city surveys, in large bridge construction planning, large engineering projects involving flood control, navigation, and hydro-electric developments, in subsidence studies, and in the planning and construction of the federal highway systems. The rigid location of national, state and local boundaries, as well as private property lines is dependent upon a national system of geodetic vertical and horizontal control for permanence, accuracy and precise recoverability.

The horizontal control surveys determine the latitude and longitude of marked points and prominent natural and cultural objects as well as azimuths and lengths of the observed lines. The field operations for horizontal control include reconnaissance, measurements of base lines, geodimeter length determinations, astronomic determinations (particularly Laplace azimuths), triangulation, and traverse. Triangulation operations comprise the greater portion of the field work. Networks of arcs of triangulation extend over the United States. The arcs are formed by chains of triangles arranged in quadrilaterals and central point figures. The areas between the arcs are being filled in with a continuous net composed mostly of connected single triangles. For basic control, it is planned to have at least one station established near the corner of each 7½-minute geographic quadrangle and to have permanent points at 4- to 5-mile intervals in the vicinity of main highways.

The main arcs comprise first-order triangulation, the criterion for which is that the discrepancy between a computed length and the measured length of a base or the adjusted length of a check line shall not exceed 1 part in 25,000 after the angle and side equations have been satisfied. The average discrepancy of this type is about 1 part in 75,000. Also, the allowable closure of a first-order triangle does not exceed 3 seconds, nor the average closure exceed 1 second. Modified second-order triangulation, which is used to fill in the areas between arcs, is observed with first-order instruments and slightly modified procedures with a maximum allowable triangle closure of 5 seconds and an average closure of about 1.5 seconds.

Triangulation observations are made with high-grade first-order direction theodolites, usually at night on signal lamp targets. In many areas of the country, triangulation surveys have been greatly expedited by using Bilby steel towers. This is a double tower formed by two demountable portable steel tripods. The inner tripod supports the instrument independently, and the outer tripod supports the observing party, tent, signal lamps and other gear. These towers can be built in a few hours to heights of from 37 to 116 feet, and can be taken apart in even less time, hauled by truck to the next site, and re-erected many times.

Base lines and Laplace azimuths are included in arcs of triangulation at intervals, in order to maintain strength in length and orientation. First-order bases are measured with probable errors not exceeding 1:1,000,000, using standardized invar tapes under standard tensions and methods of support. Corrections applied include those for temperature and inclination. The geodimeter is used for some base measurements. This instrument developed to utilize the speed of light precisely, is used to measure many of the more difficult base lines where terrain prohibits or retards the conventional methods. Laplace azimuths are observed with methods to ensure that the probable error will not exceed 0.3 second.

All points in the continental geodetic network of horizontal control are referred to the same datum (the North American 1927 Datum) and are therefore correctly related in position with respect to each other, regardless of their distance apart. The Clarke Spheroid of 1866 is the basis of computation.

Descriptions of stations and geographic positions are published for public use. The plane coordinate positions on the adopted state plane coordinate system are also published for all adjusted positions. The geographic positions have been determined for approximately 160,000 stations in the United States and Alaska, consisting of marked or monumented points and prominent objects. Stations are marked by bronze discs set in concrete monuments, bed-rock, structures, etc. The present standard complete marking of a triangulation station consists of a station (center) mark, an underground mark, 3 feet or more below the center where practicable, two or more reference marks, and an azimuth mark visible from the ground and usually about one-quarter mile distant. During an average year's work about 100,000 square miles of triangulation are completed, and about 3,000 geographic positions are established About 25 base lines, average length about 6 miles, are measured each year.

The vertical control surveys determine elevations of the network of bench marks which extend over the United States. The elevations of 340,000 bench marks have been determined by approximately 164,000 miles of first-order leveling and 250,000 miles of second-order leveling. The main nationwide network of first-order levelling has been established with lines spaced 60 to 100 miles apart. With the exception of necessary re-leveling for reasons of recovery and to bring vertical control established prior to 1916 up to present standards the main network is complete. Second-order leveling is being established within the first-order loops to provide a planned line spacing of approximately 6 miles. Most of the lines follow the routes of highway and railroad systems for economic reasons. At present, bench marks are set at intervals of one mile or less along the lines. The standard bronze disc marks are set in concrete monuments, bed-rock and permanent structures. The datum used by the Coast and Geodetic Survey is the mean sea level (sea level datum of 1929). The elevations of over 8,000 bench marks are determined annually and about 7,500 miles of first- and second-order leveling are run.

Gravity stations are well distributed over the United States. Pendulum gravity determinations are being supplemented by gravity meter observations. The basic net of pendulum gravity stations provide data at intervals of about 100 miles over most of the United States. It is planned to provide a more dense distribution of gravity information with gravity meter stations spaced about 6 miles apart. An area of about 900,000 square miles in the central United States is now covered by gravity surveys at a six-mile spacing.

Variation-of-latitude observatories are in continuous operation at Ukiah, California, and Gaithersburg, Maryland. These are two of five observatories, spaced around the earth on the same parallel of latitude, which take part in an international program of observations to detect the movements of the axis of rotation of the earth. In addition to astronomic azimuth and longitude observations which are made at the numerous

Laplace stations of the triangulation scheme, latitude observations are usually made at the same time for use in figure-of-the-earth studies. Over a thousand astronomic stations have been established and more are being required as the horizontal control is extended.

The administration, compilation, and computation work of the Geodesy Division is divided among four branches consisting of Triangulation, Levels, Gravity and Astronomy, and Operations and Information. The primary functions of the four branches include the mathematical adjustment of the horizontal and vertical control survey networks in the United States and its possessions; the review and processing of gravity and astronomic observations received from the field; the gravity and astronomic computations required to fix the horizontal control network; the planning and coordinating of field activities; and the publication and distribution of geodetic control data.

Special functions of these branches include the adjustment of foreign surveys; the preparation of tables of map projections, grid intersections and loran data; the determination of inter-continental distances requiring geodetic evaluation of the relative positioning of the world datums and the size and shape of the earth; the preparation of the State Plane Coordinates; the investigations and computations contributing to scientific and technical studies involving crustal movements particularly in earthquake and subsidence areas; investigations of the effect of irregularities of the earth's gravity field on the flight of guided missiles; evaluating suggested improvements to operations; and coordinating all geodetic operations with the current needs of other agencies and organizations engaged in mapping and engineering endeavors.

Topographic Surveying

Large-scale surveys of the topography of the coastline and the immediately adjacent land areas are essential to the production and maintenance of nautical charts; consequently, since its inception, the Coast and Geodetic Survey has been engaged in mapping the coastline. For the most part, the coastal mapping executed by the Survey is limited to terrain features adjacent to the shoreline and other land features that are essential for control for hydrographic surveys and which are also necessarily shown on nautical charts as aids in alongshore navigation. With the advent of radar navigation, landforms are becoming increasingly important to the navigator. In recent years, large scale mapping, particularly of airports, has been undertaken for the production and maintenance of certain aeronautical charts and for the production and maintenance of a series of Airport Obstruction Plans used by the Civil Aeronautics Administration and the Air Carriers for determining the maximum safe weight of aircraft for landing and takeoff in reference to existing obstructions and other factors.

Coastal mapping comprises a relatively narrow strip ranging from 1 to 10 miles inland from the coast and extending along the entire sea coast of the United States and its territories, around bays, and up rivers to the head of navigation. Each map is basically a planimetric map compiled at the same scale ratio as the inshore hydrography, that is, 1:5,000, 1:10,000, or 1:20,000. Contours are included when needed for charting, or in some cases when requested by other agencies of the government. When the maps include contours, the manuscripts are loaned to the U.S. Geological Survey and the Army Map Service for publication as basic components of the standard topographic series of the United States.

Mapping of airports includes the preparation of a planimetric base map at a scale of 1:12,000 and the inclusion thereon of the positions and elevations of objects constituting obstructions to air traffic and of other information relative to control of air traffic.

All of the maps mentioned above are made available to the public in the form of photographic copies at the original manuscript scale. These maps represent a valuable and unusual map record of the coastline and of airports and the changes that have occured from time to time. Consequently, they are used extensively by other agencies of the government and the public for engineering planning and development, in connection with property ownership where the shoreline is a property line, for resource exploration, and for control of coastal erosion.

Until the advent of aerial photography, ground planetable surveying was used exclusively by the Coast and Geodetic Survey as the method of making topographic surveys. Ground topographic methods have given way to the more economical and more expeditious method of photogrammetry which was first used in surveys made in connection with the Alaska-Canada boundary in the 1890's. At that time photographs were taken from the ground at points of known position and were used in lieu of planetable observations to determine the positions of minor points and other details. Although the method (terrestrial photogrammetry) was used with considerable success, it was not generally adopted and photogrammetry was not used again until 1918 when some aerial photographs became available for experimental surveys. This new method, more complete in coverage and less tedious in application, soon demonstrated its superiority over ground planetable surveying, and since 1928 has developed rapidly to the point where it is now used for nearly all our mapping for the production and maintainence of nautical charts.

Much of the mapping done by the Coast and Geodetic Survey is confined to a narrow belt around the coastline of the United States and its territories where the shoreline is broken by the many water areas of bays, inlets, and rivers. Consequently, the mapping problem is different from that pertaining to the mapping of inland areas and the Bureau has developed special instruments and procedures to meet this specific situation. Principal among these is the nine-lens aerial camera that was designed by the Bureau, first used in 1937, and is still in use today.

The camera has nine lenses of 8¼-inch focal length which produce at each exposure nine separate images on one piece of film. The images are transformed and combined in a special optical printer into a composite photograph approximately 35 inches square. These transformed prints afford excellent, detailed views of the ground. Each photograph covers an angle of 135° and provides coverage of an area of 32 square miles when taken at an altitude of 7,000 feet. This coverage increases to over 300 square miles at an altitude of 22,000 feet. The large area covered by a single exposure with this camera reduces the ground control necessary for aerial photographic surveys and reduces the cost of surveying with photographs, especially in areas where transportation is difficult and costly.

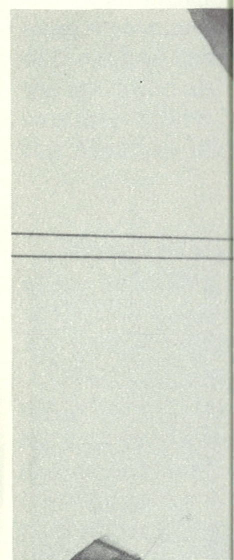
Stereoscopic plotting instruments have been designed especially for use with the large nine-lens prints. Stereoscopic pairs of rectified aluminium-mounted photographs are used on these plotting machines which are known as Reading plotters, after their designer, Captain O. S. Reading, U.S. Coast and Geodetic Survey. A visual relief model is obtained by the simultaneous examination of an overlapping pair of photographs and, by means of automatic parallax-analysing mechanisms and scale correctors, heights and contours are accurately measured and traced by this equipment.

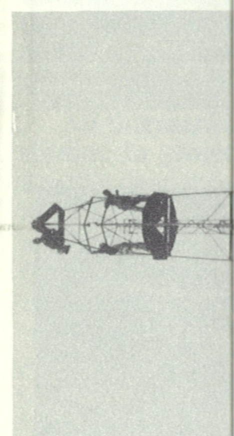
The nine-lens camera is particularly effective in remote areas such as Alaska where photographic weather is at a premium and in areas such as the Louisiana Delta and west coast of Florida where terrain conditions are difficult and ground control especially expensive. The normal angle lenses provide excellent definition of details with wide coverage per photograph. For our topographic mapping of standard accuracy, with a contour interval of 20 feet or larger, the camera is usually flown at 14,000 feet above the mean elevation of the terrain. The nine-lens procedure includes radial plotting with transparent vinylite template; rectification of the transformed but unrectified nine-lens photographs, and compilation of map details on the stereoscopic plotting instruments designed and built for use with these photographs.

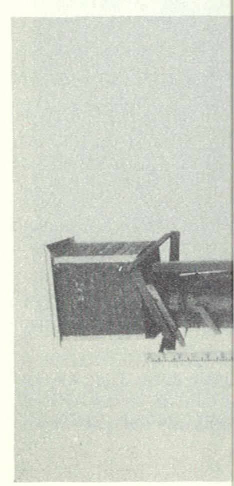
The survey also makes extensive use of single-lens photography for mapping, and for map and chart revision, in areas where weather and terrain conditions are not so difficult. Two Wild Aviogon cameras were recently acquired, one of which is equipped with an infrared cone. All photogrammetric plotting or bridging for single-lens work is done with stereoscopic instruments, mostly with the Zeiss stereoplanigraph utilizing a combined mathematical and graphic method of adjusting the bridges. In this procedure, coordinates of pass points and control stations are read from the instrument, the bridge is translated to ground coordinates, and pass point positions computed by means of IBM computing equipment of the Geodesy Division.

Map delineation is usually accomplished with Kelsh plotters or multiplex instruments. At present, the Survey has two Zeiss stereoplanigraphs, five Baush and Lomb multiplex units, and six Kelsh plotters. Photogrammetric offices at Baltimore, Tampa, and Portland, Oregon are equipped with Kelsh plotters and the Baltimore Office also has multiplex instruments

Aerial photography in Alaska and much of the photography in the United States is taken from a B-17 type, 4-motored aircraft furnished by the U. S. Coast Guard under a cooperative arrangement with that agency. The Coast Guard supplies the airplane and flight crew and the Coast and Geodetic Survey furnishes the aerial cameras, and the navigator and photographer. This airplane carries the nine-lens camera and one or two single-lens cameras. The principal navigating instrument for aerial photography is a Norden Mark 2 type bombsight which is connected with the auto-pilot so that the airplane is maintained on the flight line by the navigator during photography. This airplane is equipped with a radar altimeter as well as a standard barometric altimeter. The radar altimeter is used mainly for determining the corrections to the barometric altimeter that is used to maintain the flight altitude. In taking coastal photography







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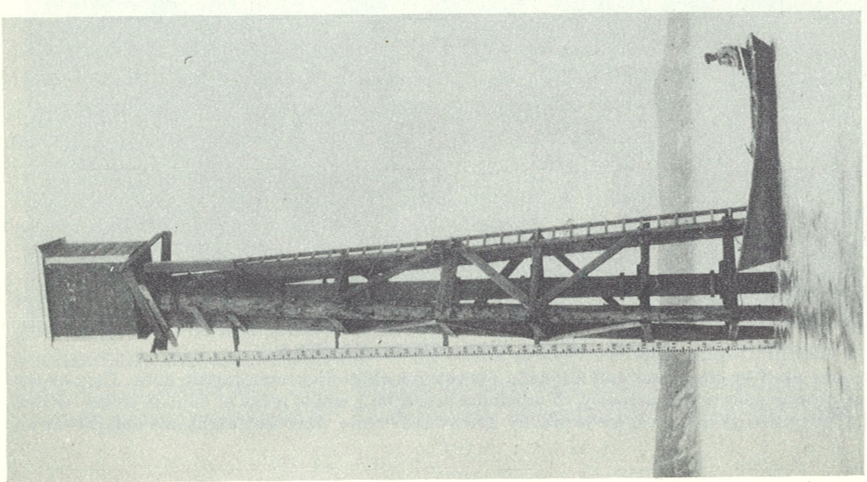

FIG. 8. TIDE GUAGE AT ANCHORAGE, ALASKA (LOW TIDE).

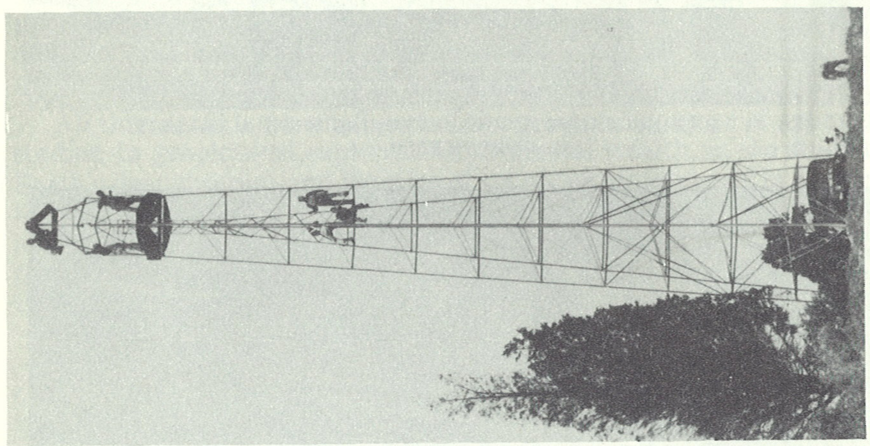

FIG. 9. BILBY TRIANGULATION TOWER. Portable steel triangulation tower designed and built for the Coast and Geodetic Survey.

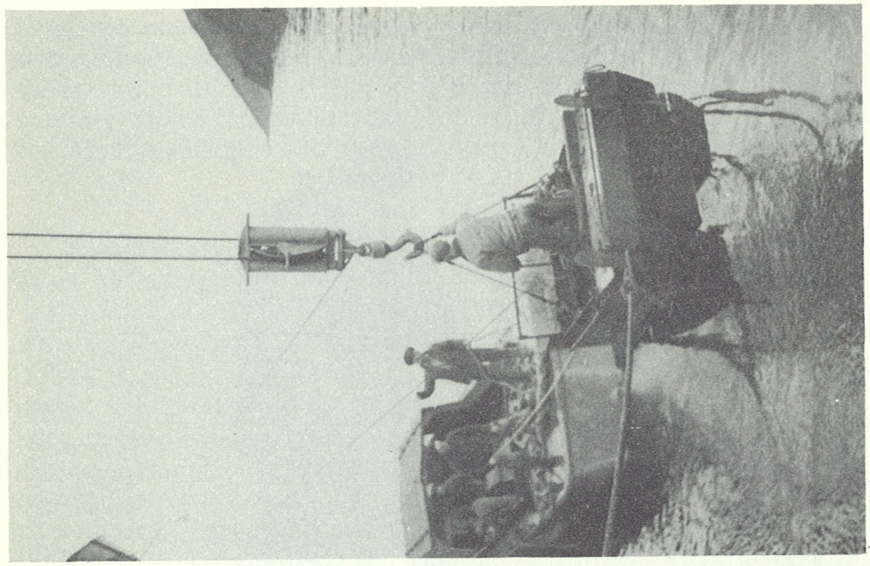

FIG. 10. PICKING UP A WEASEL AT BULDIR ISLAND.

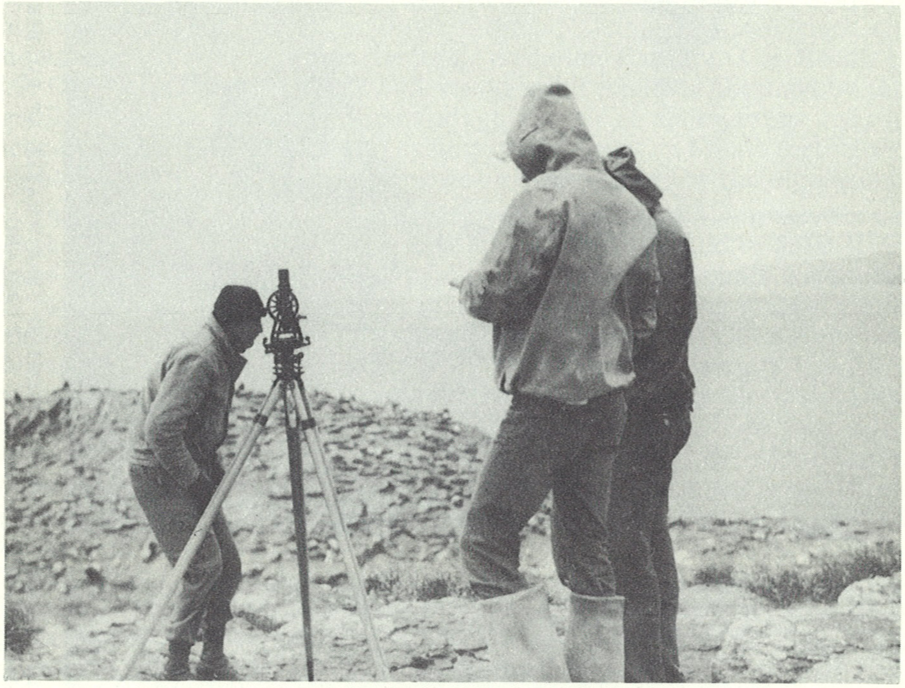

FIG. 11. MAKING MAGNETIC OBSERVATIONS WITH A TRANSIT MAGNETOMETER.

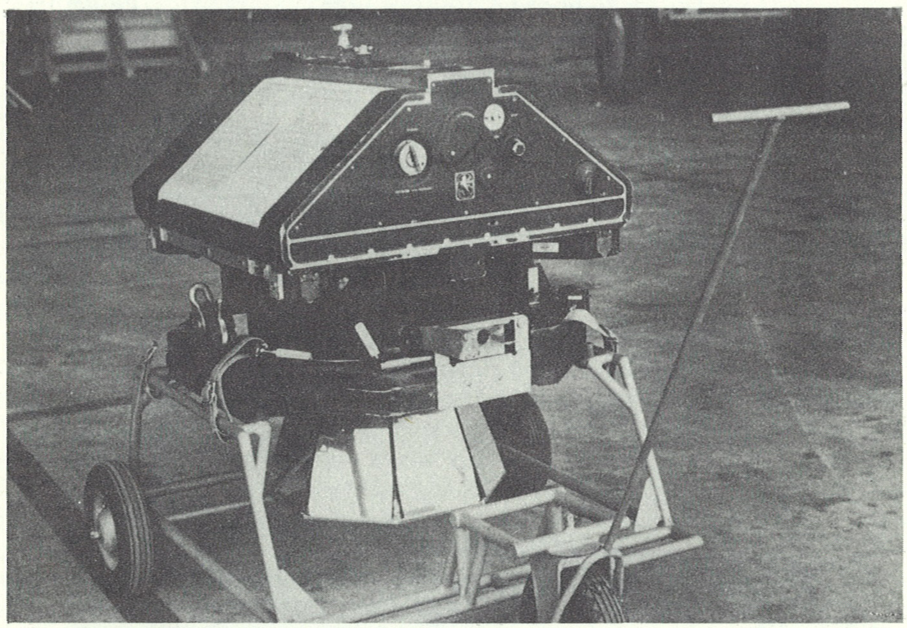

FIG. 12. NINE-LENS AERIAL CAMERA.

Designed and used by the Coast and Geodetic Survey for obtaining topographic data. The camera takes nine photographs simultaneously, of adjoining areas, on a single piece of film 23 inches square. The CENTER photograph is taken vertically downward, while the other eight are oblique views.

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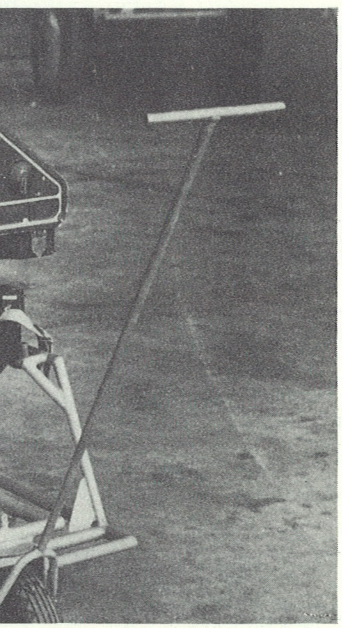

CAMERA.

aining topographic data. The camera
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the exact altitude can be determined with the radar altimeter while flying over water areas, so that corrections to the barometric altimeter can be determined frequently, whence the flight lines can be held very closely to the specified altitudes. This photographic mission operates in Alaska in the summer where the original mapping of previously unmapped coastline in the Aleutian Islands and western Alaska is still in progress.

Magnetic and Seismological Work

Mans knowledge of his enviorment on the Earth moves forward with every unfolding phase of geophysical science, each new insight dovetailing with prior gains to support vital functions of technology and modern living. Here we are concerned with the two fields of geomagnetism and seismology.

For the United States and its dependencies, responsibility for geomagnetic work belongs to the Coast and Geodetic Survey as part of its basic task of preparing charts for the navigation of vessels and aircraft. The user of the compass must depend on information which he cannot ordinarily determine for himself as to the amount that its indication departs from true north (the magnetic declination or variation). The compass has important collateral uses in land surveying and several other fields, but it is a basic tool in sea and air navigation; furthermore, the navigator must know to what extent his compass is affected by the iron in his ship. This is a difficult problem—to solve it we must know the dip and intensity of the Earth's magnetic field.

All this is still but a small part of the present-day scope of geomagnetic studies. In geophysical exploration for mineral wealth, in the study of the Earth's deep interior, and likewise of its upper atmosphere, in all forms of telecommunication, in cosmic-ray studies, in solar-activity investigations, and in the exciting new realm of radio astronomy, the findings are profoundly dependent on data about the Earth's magnetic field, its configuration and its changes.

When our atmosphere becomes ionized under solar radiation, and electric current streams are generated, or when electrified particles from the sun form into streams in space about the earth, transient magnetic fields arise. Their indications on magnetic observatory variometers are clues to conditions that produce auroral displays, disturb the ionosphere with resulting radio fadeouts and air transport interruptions, and impair geophysical prospecting operations and other technical works. The geomagnetic transient fluctuations are tangible and easily metered. Moreover, they appear to precede the other effects, generally giving this area of observation an important function as an alerting index respecting the others. For instance, the predictions of radio-wave propagation conditions by the National Bureau of Standards are strongly based on the indications of magnetic observatory instruments.

Magnetic Surveys.—Prior to 1850, A. D. Bache (the second Superintendent of the Coast Survey) personally engaged in and directed the initial geomagnetic work of the Survey, including observations for magnetic declination, dip and intensity. This work accorded with the original Hassler plan which prescribed that "magnetic bearings should be regularly observed at each principal station." These early observations were confined to the coastal regions, since they were intended to provide magnetic data for nautical charts. Later the work was extended to the interior of the country, and it was greatly expanded and intensified at the turn of the century. To meet the practical charting requirements as well as the diverse needs exemplified above, an effective and well-balanced program has been evolved, calling for long-range coordination of work over a vast area, and hence for the functioning of a technically qualified staff devoted to these activities.

Magnetic observations have been made at many thousands of stations including nearly all of the more than three thousand county seats in the United States. Magnetic observatories have been set up at a score of places, and seven of these continue in permanent operation to record in detail all the fluctuations and gradual changes that are manifested in the magnetic field. The latest of these is a completely up-to-date establishment near Fredericksburg, Virginia, equipped with facilities for testing and calibrating geomagnetic instruments under simulated conditions of all parts of the globe, and with the most advanced instruments for keeping track of the fluctuations in the earth's field at the observatory. Of the other observatories, one is in Arizona, one in Hawaii, and one in Puerto Rico, while three are in Alaska. The slower changes are further monitored at about 150 selected stations where "repeat" field observations are scheduled at about five-year intervals. Detailed examination is made of the local patterns encountered at the compass testing platforms of air fields, safeguarding an important function. The latest airborne equipment is used for magnetic surveys of remote and inaccessible regions.

The Coast and Geodetic Survey regularly issues magnetic charts that provide a basis for estimating magnetic elements in any given locality. Publications are available giving general information about the Earth's magnetic field, the effects of daily variation and other transient fluctuations, and various other aspects of geomagnetism. In addition, an energetic program is promoted in the survey for working out new techniques and developing new instruments for the highly refined measurements that provide the basis of an all-out program of magnetic work.

Seismological Surveys.—Records obtained at magnetic observatories occasionally showed peculiar oscillations which where associated with distant earthquakes, suggesting the possibility that earthquakes might produce magnetic phenomena. The effects were later found to be mechanical. However, before the question could be settled it was necessary to install seismographs at the observatories. With this background in seismological work, the Coast and Geodetic Survey was eventually made the official agency of the United States Government for studying earthquakes and learning as much about them as possible, for both utilitarian and purely scientific purposes. The Survey also assists in coordinating the work of universities and other institutions in this field, and serves as a clearing house for the results they obtain. In such ways the efforts of the Bureau yield returns far beyond the level of its own expenditures.

The most urgent practical need is for information leading to the prevention of earthquake damage and loss of life. The most direct approach to this problem has been the strong-motion program, begun in 1932, whereby instruments that measure the forces produced by strong earthquakes are operated in localities where earthquakes are considered likely to occur. At the end of the year 1955, 71 strong-motion seismograph stations were in service. A number of foreign countries have adopted strong-motion programs patterned after ours. More than 1300 strong-motion records have been obtained, and information derived from them has contributed substantially toward reduction of earthquake hazard.

After an earthquake occurs, questionnaires are sent to selected persons in the shaken area, in order to collect eyewitness information about the effects produced by the earthquake, the nature and duration of the shaking, and similar details. The questionnaire program also serves to delimit the felt area and the various intensity levels. These questionnaires may number in the hundreds or thousands for a single earthquake, depending on the severity of the shock.

In important earthquakes, trained personnel inspect the area and interview eye-witnesses, obtaining significant information that others might overlook.

The Coast and Geodetic Survey has long engaged in the location of earthquakes, or "epicenters," and holds world leadership today in that field. In this work we use data from our own seven seismograph stations, from fifteen others operated in cooperation with other institutions, and from several hundred world-wide independent stations. As epicenters are located, reports are sent to the cooperating stations in return for their data, and to any others who desire them. In the fiscal year 1956, epicenter information was distributed on the location of 1113 earthquakes that occured in all regions of the world.

Another hazard, wherein seismology occupies a key position, is presented by the seismic sea wave, sometimes incorrectly referred to as a "tidal wave." A number of such waves of potentially destructive magnitude have been generated in recent decades by strong North Pacific earthquakes. In order to cope with them, a "Seismic Sea Wave Warning System" has been established, incorporating a network of strategically located seismograph stations with provisions for rapid intercommunication. They are equipped with automatic alarm systems, to alert the observer at any hour, if an important earthquake occurs. By exchanging information, the observers determine quickly where the earthquake occurred. If there is danger of a seismic sea wave, a warning is promptly sent out.

This system has been possible only because sufficiently sensitive seismographs had previously been developed for the purposes of pure science—that is, for the detection and location of distant earthquakes, and the study of the structure of the Earth's interior. In fact, seismology affords the only available precision tool for delineating the structure of the inaccessible interior of the Earth. This is accomplished in several ways, principally from the study of the speeds, wave forms, and energy content of elastic waves that originate from earthquakes and travel through the earth or along its surface. Thus, seismology has been aptly called an "eye through which one may view the innards of the earth."

Combined Surveying Operations

Surveying our Alaskan waters and adjacent coastal areas has been a pioneer undertaking by the Coast and Geodetic Survey. Surveying in Alaska is at best slow and difficult due to rugged terrain, bad weather and foul inshore areas. Ice conditions and low temperatures add to the difficulties. To pursue this work successfully special planning and coordination of surveying operations have been necessary. In surveying isolated regions under adverse conditions the method of combined surveys has been developed by which each ship operates as an expedition.

The modern surveying ships in use today carry equipment and trained personnel for accomplishing all operations incidental to completing surveys in areas far-removed from home ports. Ship-based parties with personnel trained in hydrographic, topographic, geodetic and related surveys have been especially effective in conducting surveys in Alaska. In recent years extensive operations have been carried on along the bleak and barren chain of Aleutian Islands which extend more than 900 miles in a south-westerly direction from the Alaska mainland. In addition to the execution of hydrographic surveys, members of the surveying ship are required to establish geodetic control, conduct topographic surveys for the location of signals for hydrographic control and the delineation of shoreline by planetable, make magnetic observations and obtain tidal information through tide and current surveys. Also, aerial photographs are field-inspected and necessary control points are identified and described. Thus combined surveying operations with ship-based parties have come into general use as the medium for conducting our Alaskan surveys.

Nautical and Aeronautical Charts

Growing waterborne commerce during colonial days created the need for nautical charts, for guiding the mariner safely and expeditiously into and out of coastal harbors. The need for similar charts for airborne commerce arose after World War I, with the ensuing development of aviation. The Coast and Geodetic Survey is responsible for the construction, publication, and maintenance of the nation's nautical and aeronautical charts.

The first nautical chart was published more than 100 years ago from an engraving on stone of Newark Harbor. Prints from copperplate engravings were then issued until the development of photo-lithographic methods. The early engravings were characterized by the artistry of detail. Fineline engraving included elaborate views of headlands, lighthouses, and harbor approaches.

The aeronautical charting program began in 1926 with the publication in strip form of charts that followed the newly lighted airways between the major air terminals. These charts were soon followed by a series of 87 sectional aeronautical charts published for low-altitude contact flying throughout the United States.

Rapidly expanding maritime and air commerce, and developments in navigational aids and methods have increased many-fold the demand for new types of charts and modernization of existing ones, and military requirements have accelerated and magnified charting programs.

Nautical and aeronautical charts are printed in a modern humidity-controlled pressroom. The line of presses includes four two-color offset presses and six single-color presses capable of handling plates 38½ by 59 inches. Many charts are run through the presses several times in order to print the multiple colors required in accentuating various chart detail. As many as 13 printing plates are used for one aeronautical chart series. About 45,000,000 copies of nautical and aeronautical charts, and related printings, are published yearly.

The hum of the presses is no greater than the activity which precedes press runs. An adjoining room houses the graining machines where the mechanical agitation of glass graining marbles, sand, and chemically treated water prepare the surface of the aluminum printing plates for photo-lithographic processing. Nearby, motorized whirlers spread the photographic chemicals evenly over the plates; and in the same photographic room a row of large vacum frames are busily transplanting images to the plates from the glass or plastic negatives. Preceding the contact between negatives and plates are the various photographic processes employing cameras as large as the 14½-ton, 50-inch precision camera used for the largest wet-plate negatives. The cameras and developing tanks are kept busy not only with lithographic copy, but also with making copy of the various materials required during compilation of the charts.

Nautical Chart Production.—Nautical charts are compiled principally from basic field surveys made by the Bureau, and they include all information essential for safe navigation. To meet the different navigational needs, nautical charts are published in different series classified as SAILING, GENERAL, COAST, HARBOR, and INTRACOASTAL WATERWAY. Chart scales range from 1:2,500 for the largest-scale harbor chart to 1:5,000,000 for the smallest-scale sailing chart. Nautical charts are constructed on the Mercator projection.

Of the more than 800 nautical charts on issue annually, upward of one million copies are distributed. New charts produced each year total about 15. Nautical chart production also includes about 50 new editions and 400 new prints or reprints annually.

The nautical chart is designed to develop the greatest usefulness of our coastal waters and to promote safety in marine navigation through constant revisions in its contents and appearance. New surveys and resurveys of waterways and coastal topography made by the Bureau and other Federal and State agencies constantly add to the usefulness of nautical charts. Revisions in buoys and beacons which mark waterways must be promptly incorporated in the charts; and charts must be redesigned to serve new types and methods of navigation.

During the past several decades the nautical chart published by the Coast and Geodetic Survey has undergone more radical changes in appearance and usefulness than in any similar period of the history of the Bureau. Several factors are responsible for the numerous significant changes in the modern chart. These are the rapid strides in surveying techniques with the resulting augmented knowledge of the ocean floor; new navigational requirements; modernization by improved techniques and simplified symbolization; and improved reproduction methods and increased use of colors.

Because of improvements in navigational and surveying techniques, the nautical chart now utilizes to the fullest extent the wealth of submarine detail contained in modern hydrographic surveys. The sea floor is brought into graphic relief by increased use of depth curves which outline significant bottom features. The navigator can then utilize the graphic profile recorded by the fathometer, as an aid in determining his ship's position and course. In laying a new course, these outlined features can be used as check points in areas between or beyond the limits of navigational buoys.

Other navigational methods which have affected the content and usefulness of the nautical chart are radar and loran. Although charting of the shoreline is considered sufficient for radar navigation in most areas, the addition of contours, bluffs, elevated structures, and specific radar reflectors enhance the value of the nautical chart in this respect. General and Sailing charts are now covered with a lattice work of loran lines of position to facilitate navigation by this modern electronic method.

Paralleling these advances in navigational instrumentation and equipment are the increased speed and draft of ships plying the waterways. The impact of this evolution in marine commerce is not unlike changes wrought in expediting commerce on the nation's highways. Guides to transportation like the nautical chart must improve in this accelerated era.

In contrast with old charts used in the days of slow-moving sailing vessels, which emphasized artistic detail in monochrome, the modern chart simplifies detail and utilizes colors and bold symbols for improved, quick reading. The basic detail is still printed in black, but the land area in buff color contrasts with the blue tint of shallow inshore waters. An overprinting of the latter two colors in foreshore areas produces a green tint which highlights tidal flats, marshy shores and exposed ledges, as well as offlying bars and other low-water features. In the untinted deeper areas isolated shallow rocks, shoals, and other dangers are highlighted by the blue tint. Magenta color highlights certain floating and fixed aids to navigation and other features such as submerged cables and pipelines, danger and anchorage areas. As many as seven colors are used on charts showing the loran lines of position.

Aeronautical Chart Production.—The basic series of 87 aeronautical charts of the United States, previously mentioned, soon became inadequate for aircraft navigation at greater speeds and at higher altitudes. Furthermore, new radio navigational aids permitted safe all-weather flying with controlled air traffic. Additional series of charts were required for the various types of flights. Thus, a family of charts came into being that falls into two categories—for contact and instrumental flying.

Visual or Contact Flying:—Charts of this class are designed for contact flying with sufficient aeronautical information for the auxiliary use of radio navigational aids if desired. They include:

Local charts for flights into high density areas of congested airports.
Sectional charts for low altitude and slow-to moderate-speed flights.
Planning charts for planning long flights.
Route charts for navigating between large air terminals.
World charts for moderate-speed, moderate-altitude flights.
Jet Charts for high-altitude, high-speed flights.

Instrument Flying:—The instrument series carries full aeronautical information for all-weather flights and is practically devoid of any topographic information that can be used for visual landmarks. They consist of:

Radio Facility charts for enroute navigation by radio aids only.
Instrument Approach and Landing charts showing flight patterns at airports.
Aircraft Position charts for plotting positions over the principal oceanic routes used by domestic civil aviation.

About ten million copies of the 190 charts of the regular series on issue and over thirty-three million copies of the 1,290 instrument charts are printed annually for civilian and military use.

In the interest of safety, it is necessary to keep the charts as current as practicable. Charts of the Sectional and WAC series are revised one to two times per year to reflect the latest changes in landmarks, hazardous obstructions, airport data, and the changes in radio aids. The radio facility charts, however, must be kept current to an even higher degree as the pilot flying the airways entirely on instruments, in bad weather, is dependent upon the absolute accuracy of the information portrayed. The radio facility charts are issued every five or six weeks just prior to the time that major changes in the airport structure become effective. Similarly, the instrument approach and landing charts are published just prior to the effective date of a new or revised instrument approach procedure.

A staff of highly skilled researchers, cartographers, and technicians is required to ensure the usefulness and reliability of the charts. The needs of pilots and navigators of military aircraft, scheduled airlines, business aircraft and private planes must be determined and correlated. Aeronautical and topographic information needs to be gathered, evaluated, and disseminated to chart compilers. The cartographers must present the information in a clear, concise manner, giving emphasis to items of major importance. Close coordination is required with other governmental agencies and rule-making bodies to ensure that all rules and regulations affecting aeronautical charts are properly portrayed. Schedules must be prepared and maintained for the compilation, reproduction, and distribution of all the series in order that the right charts are available at the right places at the right times.

Research and Development

Because of its highly specialized acivities, the Coast and Geodetic Survey has from its inception recognized the importance of developing new and improved instruments, equipment, and techniques in order that better results might be obtained at reduced cost. Progressive research with the application of new scientific findings to our operations has been of paramount importance in developing our present-day methods and equipment. In recent years our research work has been intensified through maintenance of a Radio-Sonic Laboratory where improvements and adjustments are made of equipment used in the application of electronics to our surveying operations. Aerial photographic mapping is being continually improved through intensive research carried on in our Photogrammetric Laboratory by a technical group of experts assigned to this type of work. Improvements are being made in the quality, accuracy and speed of stereoscopic contouring with the Reading plotter. The Survey maintains a modern repair shop for servicing all instruments and equipment used in its field and office work.

Many important improvements in operating equipment and methods

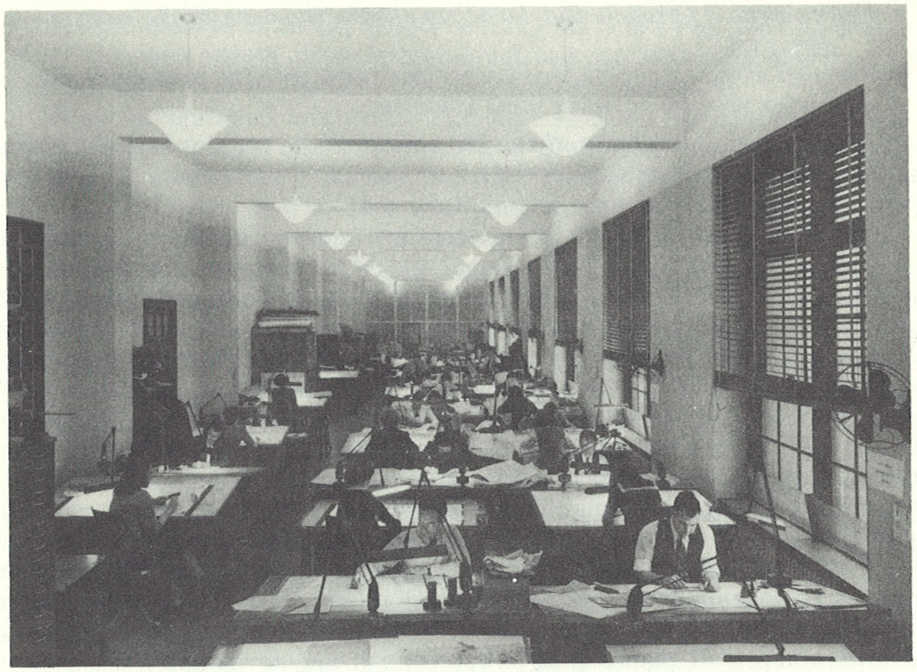


FIG. 13. ONE OF THE DRAFTING ROOMS WHERE AERONAUTICAL CHARTS ARE DRAFTED, REVIEWED AND PROOF-READ PRIOR TO REPRODUCTION.

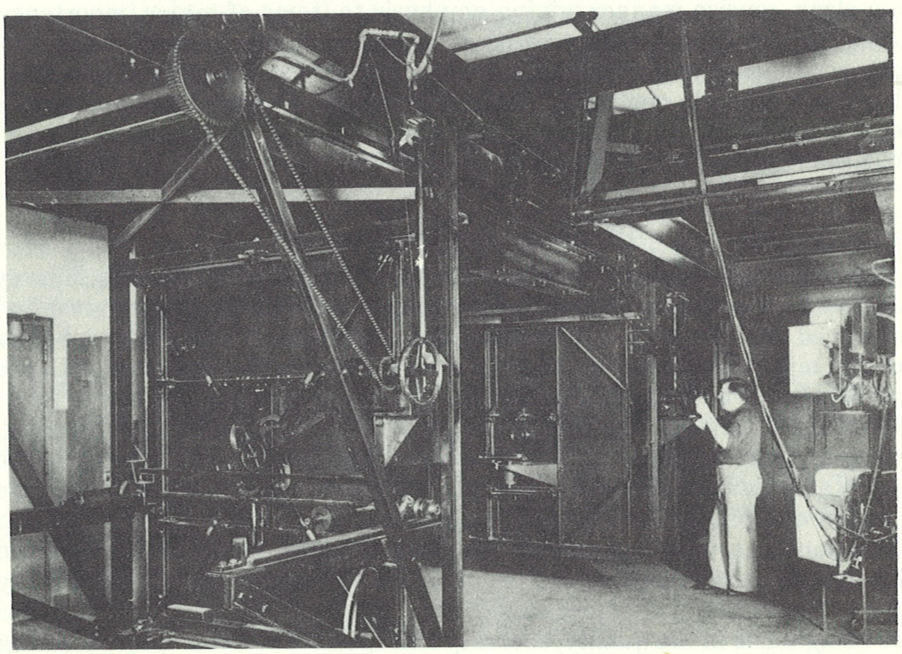
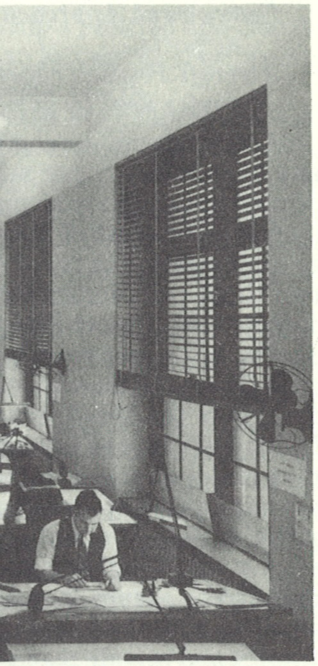


FIG. 14. LARGE 50-inch PRECISION CAMERA

Designed and used by the Coast and Geodetic Survey for the reproduction of nautical and aeronautical charts. Weighing 14½ tons, this large wet-plate camera is housed in the Department of Commerce Building, Washington.



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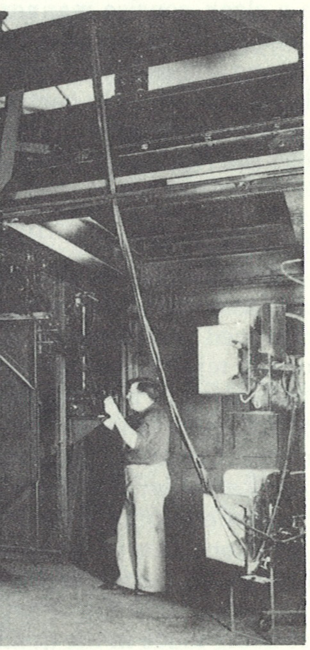

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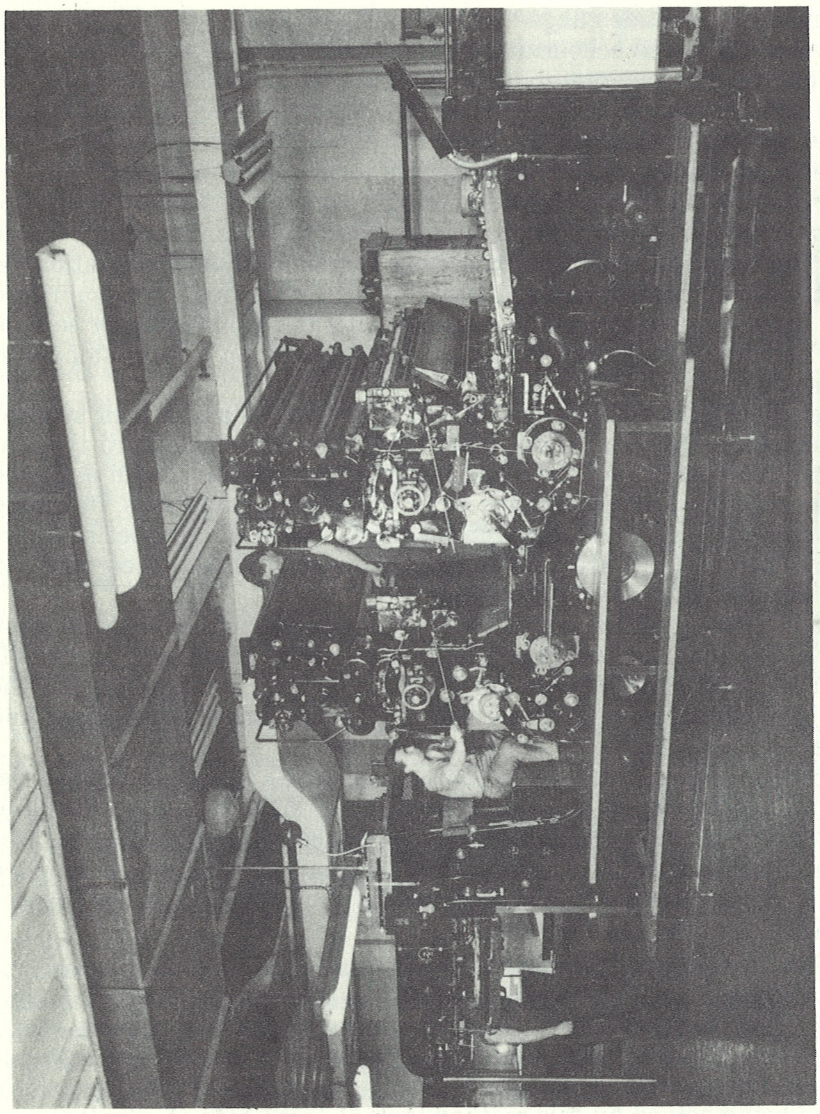

FIG. 15. TWO-COLOR OFFSET PRESS.
Two-color offset press on which aeronautical and nautical charts are printed. This press has an operating speed of 4500 impressions per cylinder per hour.

used in hydrographic surveying have resulted in extensive modernization in the field of hydrography. Work now in progress includes the design and development of a new hydrographic launch and a landing craft to handle cargoes of up to three tons. To meet the special needs of the Survey, an aluminum shoal-water hydrographic launch has been designed and is now undergoing field tests. Improvements have been made in our tide and current instruments, including modification of the NK-7 portable depth recorder for use as a tide guage.

New and advanced echo-sounding instruments, deep-water anchoring equipment for current meters and tide gauges, suitable equipment for positive calibration of sonic depth records, improved depth records, and improved logs for measuring the speed of vessels through water are among the objectives of our present research and development program.

New and improved electronic equipment has been designed for seismological work at Coast and Geodetic Survey observatories. Improved visible remote seismograph recorders have been installed at several stations in connection with the seismic sea wave warning service. An improved method was introduced recently for calibrating the galvanometric seismographs by imposing a wide range of frequencies on the seismometer pendulum.

Laboratory tests simulating tide and seiche action at detector stations have facilitated the installation of sea wave detectors. Standard types of magnetic instruments for field and observatory use have been designed and manufactured in accordance with Survey specifications, including earth inductors, magnetometers and magnetic variometers. Special photographic recorders for use in Arctic regions and visible recorders for observatory use, have been developed.

A new induction-type magnetometer, developed with the cooperation of the Naval Ordnance Laboratory, and its sucessful adaptation to aircraft use by the Coast and Geodetic Survey, has for the first time opened the way to immediate future airborne magnetic surveying of ocean areas and other regions inaccessible by ordinary methods.

Precision level rods are being constructed by an improved process developed by the Survey. A more accurate printing mask is used and facilities for handling rods are better. Through continued experimentation better paints and lacquers are being obtained. These improvements have resulted in a better finished rod which is produced more quickly and at less expense and one which is far more durable.

In 1948 the Coast and Geodetic Survey installed a group of international business machines to be used primarily for computing by the punch-card method. These machines are standard equipment such as used in large business firms. Geodetic, magnetic, tidal analysis, and cartographic computations are being made on the machines. Many of the extensive geodetic problems being solved by this method include large sets of simultaneous equations involved in triangulation adjustments. Such problems comprising more than 2,000 simultaneous equations are being completed in three or four months. Using desk calculators, the services of five men would be required for one year to solve the same problem.

Plans are now being developed for expanding geodetic control into northern Alaska by means of Shoran tri-lateration. This method offers a rapid means of locating stations for which more accurate determinations can be made at a later date by conventional triangulation.

Our extensive operations in Alaska require the development of suitable instrumental equipment and methods appropriate to the unique rigorous environmental conditions encountered in the Arctic and Sub-Arctic. All types of precise instruments require special modification to withstand the intense cold and humid conditions of Alaska. Through experimentation employing temperature chamber equipment the best metals and oils for instruments and equipment are being determined. Tests are now being conducted to determine the best material for cross lines in telescope reticules.

Improved procedures are in prospect for determining elevations through the development of techniques for use of photo-theodolites and precision altimeters. Experimentation is being made with new types of vehicles for surveys in inaccessible places such as Alaskan tundra and bog areas. Techniques have been developed for landing amphibious vehicles over boulder beaches and through rough surf. Surveying operations are being expedited through the use of helicopters for placing personnel and equipment in areas not otherwise accessible.

Research and development in cartographic and photolithographic methods and techniques for map and chart production has been carried on by the Bureau for many years. The contributions of our research in these special fields and their further application to the entire graphic arts industry has helped place the Bureau in an enviable position of leadership among the map-producing agencies of the world.

Negative engraving(scribing) as a method of preparing final map and chart copy for both new chart production and the revision of existing charts was pioneered and developed by the Bureau. In 1935 special emphasis was placed on the design of instruments specifically suited for the engraving technique and the first instrument was built that departed from the traditional lithographic needles of the past. There followed a rapid development in this work and by 1940 the rigid graver, swivel graver, fine-line graver, and subdividing and building graver had been designed and built by the Bureau and negative engraving became the principal method of preparing final copy. These engraving instruments are still the basic tools in use today. In recent years the engraving technique has been universally adopted by map and chart producers throughout the world and has practically replaced the conventional method of drafting with pen and ink. The various instruments and materials are now available commercially for engraving on glass or plastic.

During the early stages of World War II, Vinylite plastic sheeting attracted the attention of map makers and its uses were quickly exploited by the Bureau for cartographic and photolithographic applications. Techniques were developed employing modified surface and deep-etch platemaking methods to produce blacklines, bluelines, positives from positives, negatives from negatives, and color proofs directly from negatives or positives on Vinylite. The extension of these techniques to the preparation of tints for gradient elevations resulted in the important economies over conventional methods. In recent years new plastics, notably Mylar, have taken their place in cartographic and reproduction uses.

The combination of tones of the same color on one printing plate offers many advantages of economy and accuracy in the press. The Bureau developed techniques for the manufacture of large-size dot and ruling screen films in a wide range of tone values. These screen films are interposed between the negative and the plate at the time of platemaking thus permitting the use of open negatives which facilitate corrections. Copies of these screen films have been supplied at a nominal cost to commercial and government printers throughout the world.

Unprecedented accomplishments in the field of cartography and photolithography during this modern age of scientific discovery and development are resulting in refinements of methods, new types of cartographic materials, and vastly improved equipment undreamed of a few decades ago. Intensive research and development programs that are expected to continue in these areas will be reflected in still greater achievements in map and chart production.

Present Operations and Plans for the Future

In view of the present strategic importance of Alaska major emphasis is being placed on the extension of our hydrographic surveys in the area. Survey vessels operated during the summer working season in various Alaskan waters. Other hydrographic surveys are carried on in various regions along the Atlantic, Gulf and Pacific coasts of the United States as a part of the present program of modernizing our nautical charts. Wire drag surveys for locating sunken wrecks and dangers to navigation are conducted in New England and Alaska or in other areas as the need arises.

Aerial photographs are taken regularly with the nine-lens camera of areas along the Atlantic and Gulf coasts and in Alaska. Photographs are also taken of many airports in the United States; surveys are completed annually for over 40 airports for use in compiling aeronautical charts for making instrument approaches and landings and for airport obstruction plans. Photogrammetric field surveys are engaged in work along the coasts of the United States and Alaska.

The basic networks of horizontal and vertical control are being extended in the United States and in the interior of Alaska. Special geodetic field projects are being assigned as needed to provide data for the new nationwide highway building program.

Our present program of tidal observations is carried on at the principal seaports in the United States and possessions and in foreign areas to provide data for prediction of tides and studies of mean sea level. The collection of temperatures and densities of sea water at tide stations is a continuing operation and a number of new stations are added to the network each year.

Data are provided regularly for further mapping of seismic areas and for the development of safe building-construction methods by the chain of seismograph stations maintained by the Survey. Data thus obtained are supplemented with information furnished by universities and private institutions. Over 9000 earthquake messages are received annually through national and international cooperating agencies; announcements are made of the locations of more than 600 earthquakes.

Plans for the future include an accelerated program in support of the economic and industrial expansion of the nation. More complete coverage of geodetic control, basically essential in the national highway building program, the President's water resources program, and a variety of other purposes, will be supplied to meet anticipated demands. The geodetic program of the Bureau provides basic data essential to all large-scale engineering activities concerned with development of resources.

Intensive hydrographic surveys out to the edge of the continental shelf is a challenging task for which detailed planning is required. Public Law 212, 1953, claims for the United States the vast underwater area extending from the shoreline to the continental slope comprising more than 2,000,000 square miles, together with the resources beneath the ocean floor. Detailed and accurate nautical charts, showing clearly the bottom characteristics of this marginal sea, are essential to the development of these resources of the future.

Other plans for the future include expanded programs in tides and currents work, aeronautical charting, and geophysical research. Already geophysical and geodetic research in the Coast Survey have provided valuable data for the defense of the Nation and the advancement of science and engineering.

Many of the present practices and techniques used by the Bureau in both office and field were first presented informally in publications issued more or less periodically since 1930. These publications provide a medium for exchanging ideas between our scientifically trained officers and employees on widely separated assignments in engineering work. Through these informal technical discussions officers keep in touch with and receive the maximum benefit from the efforts and experiences of one another. New methods and new developments are thus exposed to discussion and modification and made available to field parties for trial or application. No regular schedule is maintained but the material is printed as it accumulates and at such intervals as to be of maximum use to operating units. In addition to being of great value to the Survey, the publications render indirectly a valuable public service.

The work of the Coast and Geodetic Survey is a pioneering effort which has expanded progressively in scope and importance with the increased demands for ous products. The development and extension of our technical services and their importance in contributing to the general welfare of the nation are apparent. Each successive decade has seen a broadening of our operations with improved techniques and methods. Future operations are being planned to keep pace with modern developments in commerce and business and to meet the increased demands made upon us in preparing for National Defense. Our labors must continue with unabated vigilance so long as the sea washes our coasts, rivers flow and deposit their silt, earthquakes occur, and other changes are made by man and nature. The necessary services performed by the Coast and Geodetic Survey reveal their value in the inestimable wealth of added security to life and property on land and sea.

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